PREFACE

The U.S. Plastics and Synthetic Materials Industry Since 1958 is a product of the Industrial Analysis and Productivity Research Program (IAPR) of the Office of Business Analysis.

Instituted by Michael F. Mohr, Director of the Division of Capital, Energy, and Productivity Studies, the program's purpose is to develop a comprehensive analytical capability that can be used to examine economic policy issues that affect the production processes of individual industries. 1/

This is the first of a series of **Studies in the Economics of Production** reports designed to provide a comprehensive collection of analyses of selected U.S. industries. 2/ These reports are intended for government and business policymakers.

PART I develops and analyzes broad trends in production, consumption, technology, and import penetration that have contributed to the historical profile of the U.S. plastics and sythetic materials industry (SIC 282) since 1958.

PART II analyzes the changes that have occurred in the quantity, quality and price dimensions of each of the four major input categories -- capital, labor, energy, and materials -- used in the production process of the plastics and synthetic materials industry. PART II concludes with a description of the input substitution patterns that have occurred since 1958 and relates these patterns both to the development and use of new technologies and to the relative growth in the prices paid for the services of individual inputs.

PART III concludes the study by synthesizing and summarizing many of the major findings from PART II within the context of a comprehensive analysis of the industry's performance as an efficient producer. The changes and trends in PART II are translated into a framework which emphasizes the linkage between the industry's ability to compete and the growth patterns of its input prices, productivity, and unit costs of production. Using this framework, PART III analyzes the U.S. plastics and synthetic materials industry's performance with respect to:

- the relationship between its unit output prices and unit total costs;
- the productivity growth obtained from its inputs -- both total factor and single factor productivity -- relative to that achieved in other selected U.S. manufacturing industries;
- the relationship of its input-specific unit costs of production to input-specific productivity and price experiences;
- the evolving contribution made to the growth in its non-capital unit total cost of production by each of three broadly defined noncapital inputs to its production process; and
- the performance of the plastics and synthetic materials industry in controlling

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1/ A full discussion of the IAPR program is found in "An Introduction To The Industrial Analysis and Productivity Research Program of The Bureau of Industrial Economics", BIE Staff Paper No. BIE-SP80-1, November, 1980.

2/ Studies of the U.S. Primary Iron and Steel Industry (SIC 331) and of the U.S. Motor Vehicles and Parts Industry (SIC 371) are scheduled for publication in March, 1985.

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its total input and individual input production costs, compared with the performances of other selected U.S. manufacturing industries.

This report was prepared under the general supervision of John E. Cremeans, Director of the Office of Business Analyses. It was jointly produced by the Business Issues Analysis Division, the Statistical Staff, and the Capital, Energy and Productivity Studies Division. Donald Dalton wrote PART I. Paul Christy, Joseph Correia, Joseph Modrak, Michael F. Mohr, Betty Ng, Lorraine Pitts, Ken Rogers, and Robert Wendling developed the tables and graphs used in this report and wrote PARTS II and III. Flora Cole and Jean Shamberger provided the word processing support.

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EXECUTIVE SUMMARY

The accompanying report, **The U.S. Plastics and Synthetic Materials Industry Since 1958**, is based on new estimates of output, investment (including pollution abatement investment), capital stocks, capacity utilization, return on investment, composition of the labor force, labor compensation, energy, and material inputs of the 1958-1980 period. These estimates were prepared by the Office of Business Analysis based on data from the Census Bureau, the Bureau of Economic Analysis, the Bureau of Labor Statistics and other government and non-government sources. They are internally consistent and consistent with the 1972 Standard Industrial Classification code. These new data permit analyses not previously possible.

This study is one of three industry reports in the series, **Studies In The Economics Of Production**; reports on the Primary Iron and Steel Industry and the Motor Vehicles and Equipment Industry are also scheduled for publication in 1985. These studies are products of a departmental Strategic Planning Objective initiated several years ago to increase our knowledge of the economics of production and of productivity growth.

Background

The U. S. plastics and synthetic materials industry (SIC 282) consists of three chemical industries: synthetic rubbers (SIC 2822), plastic materials and resins (SIC 2821), and man-made fibers (SIC 2833 and 2824). Their products are in the middle of the production stream between feedstocks and fabricated goods. The final stage of processing into consumer and industrial products is usually carried out by other, non-chemical, industries such as tires and fabricated rubber products (SIC 3011, 3069), fabricated plastic products (SIC 3079), and textile mill products (SIC 22). */

The plastics and synthetic materials industry has been a "high technology" industry since its inception--long before the term came into popular use. Technical innovations and new materials have enlarged the industry's market, substituting plastics for natural fibers, glass, paper, iron, steel, copper, aluminum, natural rubber, and glues in the textiles, packaging, building materials, automotive, computer and office machine, rubber products, aircraft, adhesives, and consumer and institutional disposables markets.

The industry's growth record is outstanding. Real output for the industry as a whole grew rapidly from 1958 to 1980, but there was a wide range of growth rates among the sub-groups. (See Figure A.)

While the industry's new products created a rapidly growing market, major improvements in process-technology made the industry one of the most efficient. These production improvements include: larger, faster, continuous processing machines; new molding and forming techniques; foamed-in-place and ultra-sonic joining processes; and the use of process-control computers which began as early as 1960.

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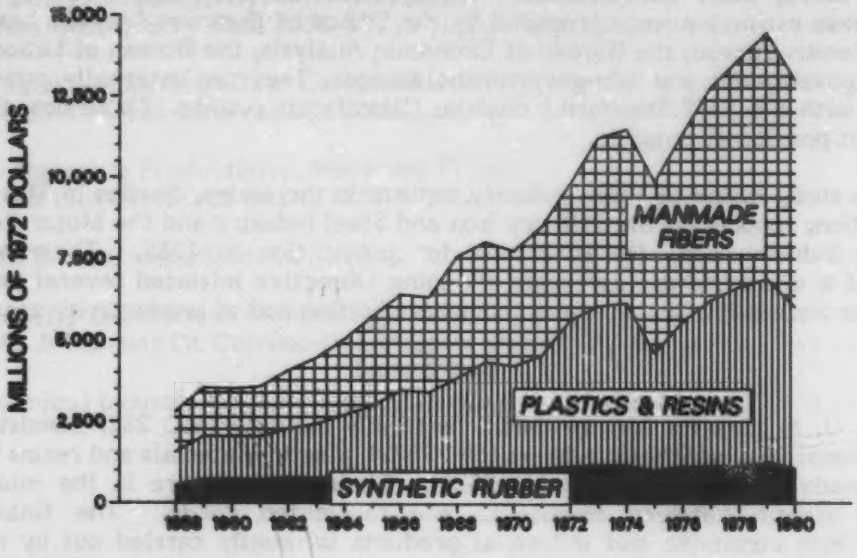
*/ A related report, "A Competitive Assessment of the U.S. Petrochemical Industry," was prepared by the Office of Productivity, Technology and Innovation (OPTI) in August, 1982. While some of the same material is covered, the present report focuses on the downstream speciality products and "pseudo-commodities" of SIC 282, whereas the OPTI report addresses itself primarily to the petrochemical commodities and feedstocks that are the inputs to SIC 282. Thus the somewhat different findings of this report are due, in part, to a difference in industry coverage.

FIGURE A

Constant-Dollar Output, 1958-80: Plastics And Synthetic Materials Industry



SOURCE: Office of Business Analysis, U.S. Department of Commerce.

The industry is materials- and capital-intensive and is affected much more severely by increasing energy prices and interest rates than is all-manufacturing. Figure B shows the revenue-share-payments to inputs as a percent of total revenue over the three peak-to-peak intervals.

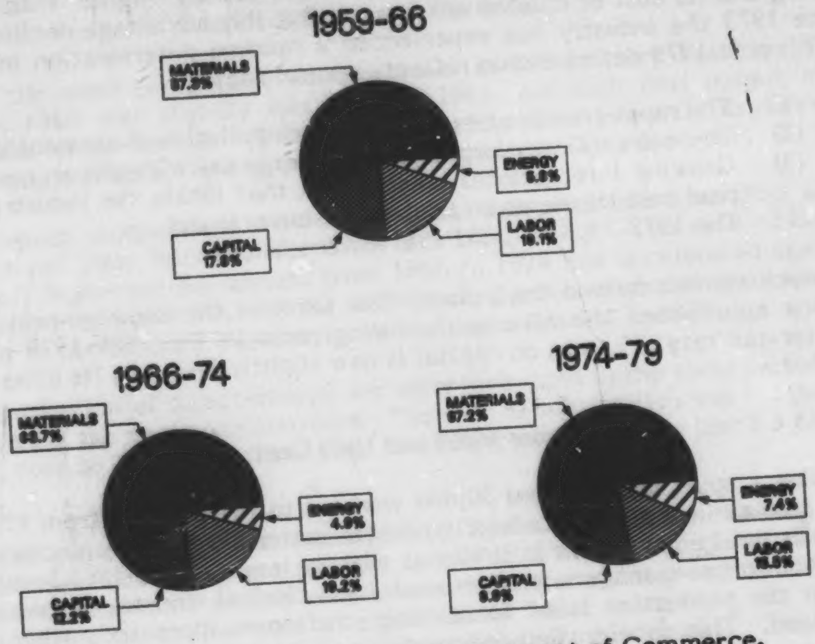
International Trade

Exports have substantially exceeded imports throughout the 1958-1980 period. A record 14.6 percent of U. S. production was shipped abroad in 1980, compared with 9.1 percent in 1958. The relatively large U. S. trade surpluses can be attributed to three factors: (1) Large economies of scale are possible; the early U.S. start plus the large domestic market permitted "world-scale" plants that captured and held a major share of the market in the 1960's. (2) A continuous stream of new products and processes from the R and D intensive U. S. industry maintained international leadership. (3) The regulated U. S. energy market, particularly for natural gas, led to cost advantages throughout the 1958-1980 period.

The domestic industry still holds the first two of these advantages, although with less surety as new plants are built in the energy-rich nations, but energy prices could in the future work against the domestic industry. The recent weakening in the world oil market increases the motivation for energy-rich nations to export energy in the form of plastics and synthetic materials.

FIGURE B

Revenue Shares:
Payments To Inputs As A Percent Of Current-Dollar Value Of Production
(Average Shares Over The Interval)



SOURCE: Office of Business Analysis, U.S. Department of Commerce.

Capital Accumulation

The industry's annual real gross investment in structures and equipment tripled over the period--from $363 million in 1958 to $1,125 million in 1980. Sharp increases in investment from 1959 to 1966 were followed by a slowdown that lasted through 1972; a brief but strong spurt of investment began in 1973 but ended in 1974 as energy prices rose rapidly and the recession sharply reduced demand. The industry's real capital stock more than tripled over the period, rising from $2.7 billion in 1958 to nearly $9 billion in 1980.

Real capital expenditures for pollution abatement structures and equipment grew from a level of $39 million in 1967 to a peak of $102 million in 1977. These expenditures were only 4.6 percent of total investment in 1967, but rose to nearly 12 percent in 1977, before falling back to 5.4 percent in 1980.

Changes in the rate of capital formation in the plastics and synthetic materials industry indicate the industry is maturing. Both the plant and equipment net productive stocks nearly doubled between 1960 and 1970; but, since 1970, the plant stock has remained virtually constant, growing at less than one percent per year. Growth in the equipment stock has also slowed sharply, falling from an average annual rate of growth of 10 percent from 1960 to 1970 to 5 percent between 1970 and 1980. The age of the industry's stock of capital, low at the beginning of the period, declined still further in the 1960's, but then rose steadily in the 1970's until it is now high compared with all-manufacturing.

Rate of Return and the Cost of Capital

From World War II until the mid 1960's, the plastics and synthetic materials industry was a "glamor" industry enjoying rapid growth and an excellent financial position. Its rate of return on capital was significantly higher than that of all-manufacturing and its cost of capital was lower. But this advantage declined in the late 1960's; since 1973 the industry has experienced a marked deterioration in its financial position. This post-1973 deterioration reflects several factors:

(1) The rapid growth of expenditures for pollution abatement capital;
(2) The extraordinary impact of the energy price shocks on costs;
(3) Growing international competition that limits the industry's ability to pass cost increases on to their customers; and
(4) The 1973-75, 1980, and 1981-82 recessions.

The stock market showed the industry less favor as the earnings-price ratio of its common stock approached the all-manufacturing ratio in the 1974-1979 period. The industry's after-tax rate of return on capital is now slightly less than its after-tax cost of capital.

Labor Input and Unit Cost

Following a spurt which added 50,000 workers to the payrolls from 1958 to 1966, employment growth in the plastics and synthetic materials industry decelerated, then declined so that total employment in 1980 was slightly less than the 1966 level. The non-production labor force--managers, professionals, and clerical workers--increased slightly after 1966; in the production labor force, only craftsmen increased, other categories actually declined. This deceleration followed a period of intensive investment in plant and equipment. Real capital per worker doubled from 1958 to 1980; real output more than doubled over the same period.

Because of the strong growth in productivity over the whole period, unit labor costs actually fell in the 1959-1966 cycle, rose at a less than 1 percent annual rate in the 1966-1974 cycle, and rose at a 4.4 percent rate in the 1974-1979 period--still 2.6 percentage points less than all-manufacturing.

Energy and Materials

The plastics and synthetic materials industry is one of the most energy intensive industries in the economy and has been forced in recent years to cope with enormous increases in its input materials bill. About 57 percent of its purchased intermediate materials and services, on a constant dollar basis, are energy-based, e.g., its feedstocks are primarily derived from natural gas.

Only about 5 percent of the industry's real intermediate purchases are for direct energy, but its efficiency in the use of direct energy has steadily improved throughout the study period. Measured as the reciprocal of BTU's per constant dollar of output, direct energy efficiency has increased at a 3 percent annual rate from 1958 to 1980. About 50 percent of the industry's real intermediate purchases are for energy and petrochemical feedstocks. The use of these materials tends to be characterized by fixed proportions and hence is less subject to conservation than is direct energy use.

The industry has increased its total materials efficiency (including feedstock materials). Measured as the reciprocal of constant dollar materials consumed per unit of output, materials efficiency has increased at the annual rate of 1 percent from 1958 to 1980. But the gains were made prior to 1973. Thereafter, improvements slowed and the industry reached its maximum efficiency in 1975. Materials efficiency has declined slightly since.

Input Substitution Patterns

One of the most remarkable developments in the industry has been that total employment in 1980 was slightly less than in 1966, although real output more than doubled over the same period. This unusual performance is partly explained by the substitution of capital, direct-energy, and materials and services for labor.

Peak-to-peak comparisons show that capital was substituted for labor at the rate of 2.5 percent per year between the 1959 and 1966 peaks. The rate of substitution accelerated to 2.9 percent per annum from 1966 to 1974 and accelerated again to a 4.7 percent rate from 1974 to 1979. At the 1979 peak, the quantity of real capital available to each worker in the industry was nearly double that available in 1959.

The substitution of direct-energy for labor was rapid in the early periods, but then decelerated during the energy-crisis years. The rate of substitution was 4.5 percent from 1959 to 1966, rose to 7 percent from 1966 to 1974, but then fell to just 2.3 percent from 1974 to 1979.

Underlying the strong substitution of capital for labor is the wave of cost-saving technical advances that swept the industry in the 1960's--most of these new techniques saved labor. An important second reason was the differential growth in factor prices. The after-tax price of capital rose at significantly lower rates than did the wages of production workers in each of the periods covered by this report. The differential changes in the prices of labor, direct-energy, and materials also explain in most of the substitution patterns among these factors, e.g., the price of direct-energy actually fell in the 1959-1966 period, explaining the substitution of direct-energy for capital.

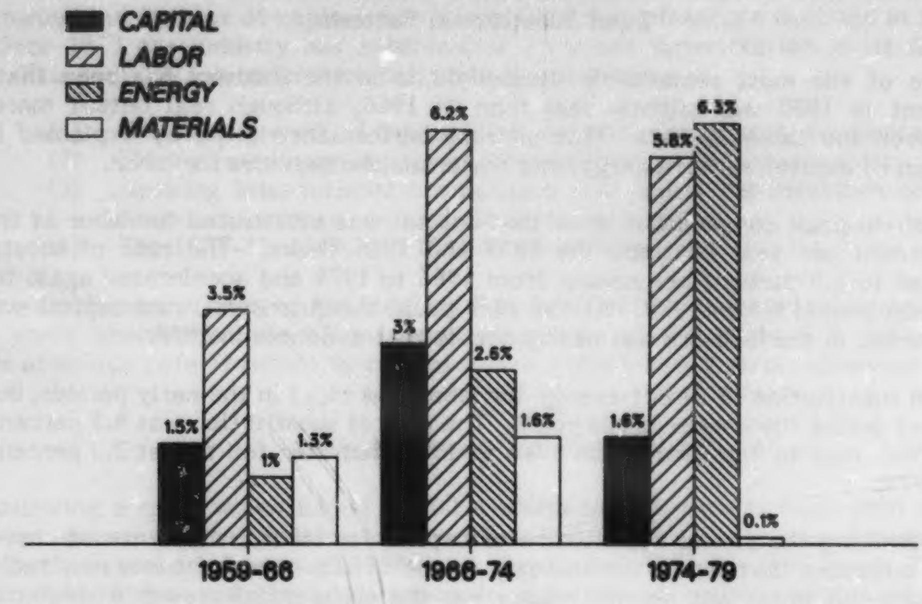
Productivity Growth

Productivity growth in the plastics and synthetic materials industry has been superior over the 1958-1980 period. Growth in total factor productivity exceeded the all-manufacturing average rate in each of the three peak-to-peak intervals; by 0.5 point 1958-1966, by 1.7 points 1966-1974, and by 0.7 point 1974-1979. The industry's productivity also outperformed that of motor vehicles and primary iron and steel. Particularly noteworthy are the rapid growth rates in labor and energy productivity. Productivity growth in materials was good in the first two peak-to-peak intervals but remained virtually unchanged over the last; not good news in a period of rapidly rising materials (and particularly feedstock) prices. (See Figure C.)

The superior productivity performance of the plastics and synthetic materials industry led to falling unit costs and prices in the 1959-1966 and 1966-1974 periods. However, rapidly rising material prices (particularly feedstocks) and virtually unchanged material productivity led to rapidly rising unit costs and rapidly rising output prices in the 1974-1979 period even though capital, labor, and energy productivity continued to improve. Strong growth in labor productivity cannot protect against rising unit costs when non-labor costs--notably materials costs--account for such a large proportion of total unit costs.

FIGURE C

Annual Rates Of Growth In Input Productivity:
1959-66, 1966-74, and 1974-79



SOURCE: Office of Business Analysis, U.S. Department of Commerce.

OUTLOOK

The plastics and synthetic materials industry has been one of the premier growth industries of the U.S. post-war economy. By any standard--growth in real output, containment of unit total costs, or growth in individual input productivity--the industry outperformed the average manufacturing industry by a substantial margin over the entire 1958-1980 period.

But the prospects for the industry are not as bright as they once were. Synthetic rubber has been a mature industry for years. Man-made fibers has achieved a 75 percent-plus penetration of the apparel market and is now expected to continue growth at a rate no greater than that of the apparel industry. */ Plastic materials and resins may still have growth opportunities, but some chemists believe that all the commercially feasible molecular structures have been identified--the future in this industry depends on finding and developing new uses of present materials.

The industry has matured and faces new problems. For the first time foreign competitors have lower costs than the domestic industry. The industry has a maturing product line and few truly new markets not previously exploited. It is no longer the darling of the stock market and so must pay average or even higher than average rates for capital. Its success in penetrating the motor vehicle, construction, and durable goods markets has made it subject to cyclical variation in demand.

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*/ U.S. Industrial Outlook, 1984. U.S. Department of Commerce, Bureau of Industrial Economics, Washington, D.C, 1984.

These new difficulties are serious, but they are not insurmountable. In fact, the short-run prospects are quite good. The industry has benefited and will continue to benefit from the current recovery, especially from the recovery of their motor vehicle, construction, and durable goods customers. Existing petrochemical plants and those now under construction in the energy-rich nations are designed to produce the feedstocks to—and not the products of—the industry, although this will likely change in the future. The industry has a long tradition of research and development and new uses of their products are still very much a possibility. In addition, there is promising research that suggests that there may be new micro-biological processes for the production of feedstocks that could reduce materials costs.

But the prospects for the industry are perhaps not as bright as they once were. Synthetic rubber has been a mature industry for years. Man-made fibers has achieved a 75 percent-plus penetration of the apparel market, and is now expected to continue growth at a rate no greater than that of the apparel industry */. Plastics and synthetic materials may still have growth opportunities, however. Some chemists believe that all the commercially feasible molecular structures have been identified, but new research involving the combining of polymers, much as metals are combined into alloys, has shown recently that there may be many new materials with useful properties that may be exploited.

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*/ U.S. Industrial Outlook, 1984. U.S. Department of Commerce, Bureau of Industrial Economics, Washington, D.C, 1984.

markets [illegible] is subject to cyclical variation in demand.

[illegible] the prospects are quite good. The industry has benefited and will continue to benefit from the current recovery, especially from the recovery of [illegible] construction, and durable goods customers. Existing petrochemical plants and those now under construction in the energy-rich nations are designed to produce [illegible] the industry, although this will likely change in the future. The industry has a long tradition of research and development [illegible]

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PART I

MAJOR TRENDS
IN THE
U.S. PLASTICS AND SYNTHETIC MATERIALS INDUSTRY
SINCE 1958

INTRODUCTION

The U.S. plastic and synthetics materials industry group (SIC 282) consists of three chemical industries: plastic materials and resins (SIC 2821), synthetic rubbers (2822), and man-made fibers (SIC 2823 and 2824). The three major industries in the group are generally classified as petrochemicals (except cellulosic fibers) because they are derived from petroleum and natural gas feedstocks, but they have little in common beyond their raw materials requirements. The largest industry in the SIC 282 group is man-made fibers, which accounted for 53.7 percent of the total group's shipments in 1980, followed by plastic materials and resins with 38.1 percent, and synthetic rubbers with 8.1 percent.

The products of the SIC 282 chemicals group are in the middle of the production stream between feedstocks and fabricated goods. The materials used to produce SIC 282 products start as petroleum and natural gas feedstocks, such as naptha and propane, which are converted to primary petrochemicals, such as benzene and ethylene; the industry is very sensitive to changes in energy prices. These primary petrochemicals are further processed into intermediate petrochemicals, such as styrene and vinyl chloride, which are used as raw materials in the production of the SIC 282 group of products--plastic materials, synthetic rubber, and man-made fibers. The final stage of processing into consumer and industrial products is usually carried out in other, non-chemical industries, such as fabricated plastic products (SIC 3079), tires and fabricated rubber products (SIC 3011, 3069) and textile mill products (SIC 22). The end-use products of the SIC 282 group include autos, carpets, clothing, construction, packaging, tires, coatings, adhesives, and electronics.

Plastic and synthetics materials are a high technology and highly capital-intensive group of industries. Real capital per worker in these chemical industries is much greater than in all manufacturing in 1979, the average capital per worker in SIC 282 was $66,000 compared with $18,000 in all manufacturing. The industry is very sensitive to changes in the cost of capital.

The end-use markets for the industries in the SIC 282 group differ widely. Synthetic rubbers are closely tied to the rubber and rubber products markets, especially tires, belts, and hoses for motor vehicles which account for about 60 percent of synthetic rubber consumption.

The man-made fibers industry is dominated by noncellulosic fiber (SIC 2824) which contributes 90 percent of the fiber industry's outputs; nylon and polyester account for about 80 percent of noncellulosic fiber output. The man-made fiber industry is closely linked to the textile industry, with its major end-use markets of apparel, home furnishings, and industrial products.

The largest end-use market for plastic materials and resins (SIC 2821) is packaging and containers, accounting for about 27 percent of consumption, followed by building and construction with about 20 percent. Other major markets for plastic materials and resins are the consumer sector with about 10 percent; electronic/electrical, 7 percent; adhesives/inks, coatings, 7 percent; and transportation and furniture with about 5 percent each.

Rapid Growth Through Technological Change And Substitution...

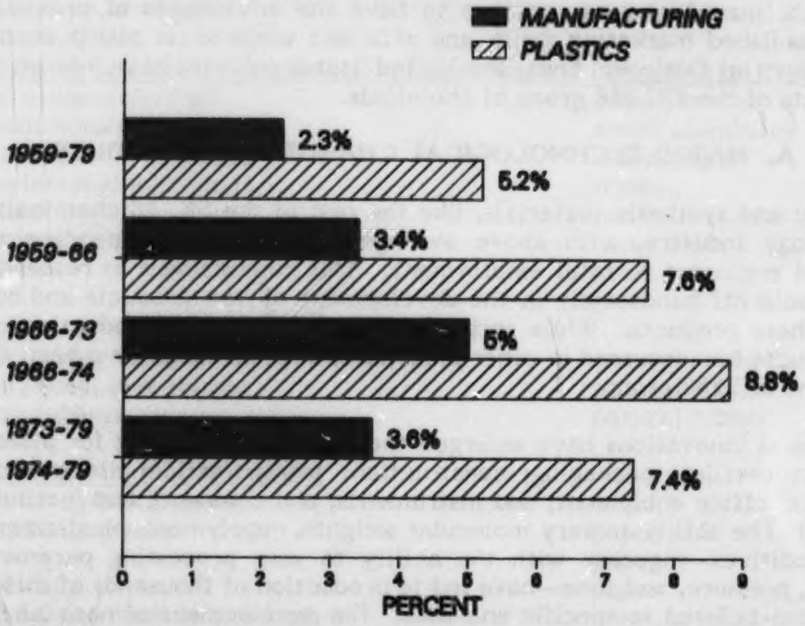
Plastic and synthetic materials shipments grew at twice the rate of the total manufacturing sector in the 1958 to 1980 period. The compound annual growth rate of the SIC 282 group, measured in constant dollar product shipments, was 7.2 percent from

1958 to 1980, compared with 3.6 percent for total manufacturing. (See Figure 1 for comparison of growth rates by major subperiod.) The source of this rapid growth in the plastic materials and synthetics industries was the rapid pace of technological change in the introduction of new plastics products which displaced a wide range of traditional metal, glass, and paper materials. In addition, low-cost man-made fibers made rapid inroads in the markets for traditional fibers such as cotton and wool. Until the 1970's, the SIC 282 industry group was favored by stable and relatively low feedstock costs, and a new, efficient capital stock.

The versatility of plastic materials is responsible for much of their growth in competition with metal, wood, paper, and glass. The development of injection and blow-molding machinery for fabricating plastic products created opportunities for high-speed production of plastic products in an endless variety of shapes and sizes. In construction, plastic pipe has made inroads in replacing steel and copper pipe, and vinyl siding is displacing aluminum and wood-based materials. In containers, glass has been displaced by blow-molded milk containers and by plastic soft-drink bottles. Paper bags, trays, and plates are being displaced by disposable plastic; plastic foam cups have captured the market for hot beverages.

FIGURE 1

Growth In Constant-Dollar Shipments
During Selected Peak-To-Peak Business Cycles:
Plastics And Synthetic Materials Vs. Manufacturing



SOURCE: Bureau of the Census and Office of Business Analysis, U.S. Department of Commerce.

Increasing Foreign Competition...

Although the international competitive position of the U.S. industry improved in the 1972 to 1980 period, clouds are appearing on the horizon which could lead to problems for the industry in the second half of the 1980's. With technology available on a worldwide basis through licensing agreements and joint ventures, the critical factors in world markets have shifted to the cost of feedstocks and to the cost of capital. The U.S. industry is expected to face difficulties in the 1980's because of the scheduled deregulation of natural gas prices and the loss of petroleum price controls in 1981. In the mid-1980's, an increasing proportion of world output of petrochemicals will be supplied by OPEC and non-OPEC oil producing countries, such as Saudi Arabia, Canada, Mexico, and Malaysia. The U.S. industry will also experience a growing disadvantage with respect to the cost of capital as many of the new production facilities in the oil-rich nations will be built with government funds or subsidized by governments.

Most of the foreign competition from oil rich nations will be confined to the "commodity" plastics in the 1980's. The focus of petrochemical development in these countries is on primary products such as methanol, ethylene, and benzene, which are not included in the SIC 282 category. However, Saudi Arabia, Canada, Mexico, Singapore, and Indonesia are building plants to produce high-density and low-density polyethylene, the highest volume of the plastic materials (SIC 2821). These countries have not announced plans to produce any of the "fine" or specialty plastic products, or enter the synthetic rubbers and man-made fibers industries.

U.S. firms will continue to play a major role as joint partners because of their expertise in marketing and quality control. The immediate impact of the increased foreign competition will be a slowing in the rate of growth of exports, because most of new production facilities in oil-rich countries are scheduled for the European and Asian markets. U.S. manufacturers continue to have the advantages of proximity to major markets, established marketing skills, and efficient world-scale plants according to the 1982 U.S. Industrial Outlook. Thus, the United States will still have a large trade surplus in the products of the SIC 282 group of chemicals.

A. MAJOR TECHNOLOGICAL CHANGES IN THE INDUSTRY

Plastic and synthetic materials, like the rest of the SIC 28 chemicals sector, is a high technology industry, with above average ratios of R&D spending to sales and scientists and engineers to total employment. This commitment to research and development has paid off handsomely in the development of new products and new processes to produce these products. While technological change in the production of fabricated end-use products has occurred in other industries, new products have been the engine of growth for the SIC 282 group.

Technical innovations have enlarged the size of the market for plastic materials and resins in textiles; packaging; construction; transportation; electronic equipment, computers and office equipment, and instruments; and consumer and institutional goods. (See Table 1.) The ability to vary molecular weights, copolymers, plasticizers, colorants, and other additives--together with the ability to vary processing parameters such as temperature, pressure, and time--have led to production of thousands of different formulations, custom-tailored to specific end-uses. The development of new fabricating technology by end-use industries--including blow-molding, injection molding, extrusions--have enabled end-users to produce plastics in an endless variety of shapes, forms, and sizes with high-speed equipment.

The major technological development in the man-made fiber industry since 1950 was the introduction of polyester fiber. Polyester accounts for much of the growth of market share of man-made fibers, from nearly 60 percent of all domestic fibers in 1969 to about 75 percent in 1979. Polyester fibers are responsible for the growth in

TABLE 1

Product Innovations In The Use Of Plastics

End-Use Market	Material Displaced
Textiles	
Man-made fibers	cotton, wool
Packaging and Containers	
Plastic bottles (P.E.T.)	glass
Plastic food tubs	paper
Plastic bags	paper, burlap
Building Materials	
Plastic pipe	iron, copper
Vinyl siding	aluminum, wood products
Plumbing fixtures (sinks, bathtubs)	steel, porcelain
Lighting fixtures	glass
Motor Vehicles	
Plastic gas tanks	steel
Radiator overflow tanks	steel
Component housings	steel, zinc
Dash	steel
Electronic Equipment, Computers and Office Machines, and Instruments	
Wire and cable coverings	paper, rubber
Component housings	steel, aluminum
Circuit boards	wood, paper
Chip carriers and mountings	none
Connectors	none
Data storage disks and tapes	none
Plastic lens	glass
Rubber Products	
Synthetic rubber tires	natural rubber
Footwear, hose, and belting	natural rubber
Speciality rubbers	natural rubber
Consumer and Institutional Disposables	
Plastic knives, forks, spoons	wood
Plates - plastic coated	paper
Trays	paper
Beverage cups	paper
Health care and medical products	glass, steel
Aircraft	
Plastic/graphite fiber composites	aluminum, steel
Adhesives	
Epoxy, phenolics	natural glues

SOURCE: Office of Business Analysis, U.S. Department of Commerce.

"permanent-press" fabrics during the 1970's. Another technological development was olefin fibers, often referred to as the "fiber of the future." The major market for olefin is carpets and carpet backing; its use is also expanding in upholstered furniture and agriculture.

In the packaging market, blow-molded gallon milk jugs made of plastic dominate this market and plastic soft drink bottles (P.E.T.) have displaced glass bottles for one and two quart size containers. Plastics are used extensively for tubs for dairy products and for all sizes of non-food containers from flower pots to trash cans. Plastic bags now compete successfully with paper bags and created a new market for trash bags. Plastic disposable items include knives, forks, beverage cups, and health and medical products.

Major new applications for plastic materials and resins include plastic pipe and plumbing fixtures in housing and construction, and the use of plastics for shower stalls, bath tubs and sinks. Another major market is vinyl siding, windows, and shutters for exterior applications in residential construction. Commercial building applications include fluorescent lighting fixtures and architectural panels. A recent innovation is the introduction of structural plastic foam, a load-bearing rigid plastic with a low-density, cellular core encased in a solid skin.

The low cost and weight-saving characteristics of plastics have led to major inroads in the motor vehicles market. Plastics usage per car increased from 12 pounds in 1959 to about 200 pounds per car in 1980, despite the decreasing average weight and size of autos during this period. Automotive applications include blow-molded tanks for fluids, vinyl tops, protective cases for parts and components; plastic is also used extensively in the form of foam for seating and dash boards. Recent innovations include high density polyethylene for gas tanks and plastic coatings for safety-enhanced windshields. In the 1980's, plastic exterior panels have been used in a limited range of production vehicles.

Plastics have played a major role in developments in the production of electrical equipment, computers and office machines, and instruments. Plastics are used extensively in these industries for component housings, wire and cable coverings, circuit boards, plastic lenses and numerous other electrical and electronic parts. New innovations in engineering plastics such as high performance polymers are expected to be important in new applications in chip carriers and mountings, connectors, data storage disks, tapes, and many other components.

Most of the technological change in the synthetic rubber industry has been concentrated on specialty rubbers, which have a higher value-added and have unique characteristics for application in a wide variety of products. These thermoplastic elastomers have the elasticity of rubber, but are processed like plastics. Specialty rubbers have increased from 25 percent of industry shipments in 1975 to over 40 percent in 1980.

The focus of most current research in product development in plastics is on engineering and fiberglass reinforced plastics which can withstand severe operating conditions and compete with steel in applications requiring high-strength and low-weight characteristics. High-strength composite materials made of plastic reinforced with graphite fibers have made inroads in the aircraft industry and in some sporting equipment, such as tennis rackets. Modified acrylics with superior impact strength are being used for street signs and polyphenylene sulfide resins are used for protective casings on electronic parts used in military and space applications.

Industry Continues To Ride Wave Of Process Technologies Introduced Largely During The 1960's...

In addition to the impressive array of major new product-innovations developed by the U.S. plastics and synthetic materials industry since 1958, there was, however, an equally impressive array of process-technologies which helped to make plastic and synthetic materials one of the most efficient of U.S. manufacturing industries. Interestingly, though, most of the cost-saving innovations were already being used by the industry by or before 1970. With few exceptions, the industry's post-1970 innovations have been modifications to and perfections of these pre-1970 innovations.

Included in the set of innovations introduced into the plastics and synthetic materials industry during the great technological wave of the 1960's were larger, faster, and more continuous process and complex machines and equipment; new combinations of molding and forming techniques; foamed-in-place and ultrasonic joining techniques; adaptions of materials for more efficient processing; and the increasing use of process control computers which the industry first introduced as far back as 1960.

Since the 1960's, however, industry experts indicate that the industry has developed and widely diffused only one major process innovation--a new method for producing low density polyethyelene (the largest volume plastics material). First introduced by Union Carbide in 1977, this new method is reported to reduce energy use by 25 percent, space requirements by nearly 90 percent, and capital investments by 50 percent.

Other innovations affecting input structure include: (1) the use of advanced catalytic agents to improve production yield, which has been highly successful in the production of polypropylene; and (2) co-extrusion--the linking of layers of plastic, each with different properties, together in a single walled sheet. The co-extrusion process has become a very important part of the packaging industry (especially for food and perishables) and co-extrusion uses entirely new equipment and production technology.

The industry is earnestly pursuing research in biotechnological techniques that will permit the production of organic chemicals through fermentation and will be competitive with synthetic organic chemicals derived from petroleum. For example, it is anticipated that it will be cheaper to produce methyl glucoside (a widely used plasticizer for rigid foams, paints, and adhesives) through corn fermentation than from petroleum feedstocks.

While not as prolific as the set of pre-1970 innovations, these direct energy and feedstock-energy saving technologies may perhaps be crucial to the long term survival of a significant segment of the U.S. industry. This is because the U.S. and synthetic materials industry is one of the most energy intensive industries in the U.S. economy and has had to cope with some of the highest energy input price increase among manufacturing industries during the 1958 to 1980 period. Over one-half of all intermediate (energy, materials, and services) inputs are energy or energy-related products. Almost 90 percent of these are used as a feedstock material in forming the industry's output. Because of this energy-intensiveness, the industry is highly sensitive to energy price increases, particularly to petroleum and natural gas products. Unlike many other industries where non-energy inputs (labor, capital, materials) are more easily substituted for energy inputs to the production process, the current technology of plastic and synthetic materials industry severely limits that option. The industry, therefore, has had to contend with rapid energy input increases. Since 1972, the price of the industry's aggregate intermediate input has increased by over 160 percent compared to just over 100 percent in U.S. manufacturing industries overall. This difference is completely attributable to the high and inelastic input mix of energy and energy products to the plastic industry production process.

Without continued innovations in energy and feedstock-saving technologies, imported plastics and synthetic materials markets may be captured by several petroleum and gas-rich countries. These countries not only have access to low cost petrochemical feedstocks, but also to low capital costs and have recently developed state-of-the-art and government-controlled petrochemical industries.

B. DOMESTIC CONSUMPTION

Increasing Cyclical Sensitivity And Changing Market Shares...

The increasing market share of plastic and synthetic materials in the construction and motor vehicle industries described in the previous section has been a mixed blessing. It has led to increased sales and production of the SIC 282 group, but it has also substantially increased the risk of major declines in output during recessions (Figure 2). In the 1970 recession, constant-dollar product shipments in SIC 282 chemicals fell 3.1 percent compared with a 5.1 percent drop in shipments of all manufactured industries. By the 1974-75 recession, the 1.3 percent decline in SIC 282 constant-dollar shipments nearly matched the 1.5 percent decline in all manufacturing; and by the 1980 recession the decline in SIC 282 was more than twice as large as manufacturing: all manufacturing fell 4.4 percent from the 1979 peak, while SIC 282 dropped 9.9 percent. In the most recent recession, SIC 282 constant-dollar shipments declined 9.5 percent, while all manufacturing declined 7.7 percent. All three SIC 282 industries--plastics, synthetic rubber, and man-made fibers--are heavily dependent on motor vehicles; for example, automobiles are the largest market for carpeting. Housing and nonresidential building are also major end-use markets for plastics and textiles, and these industries are notoriously cyclical.

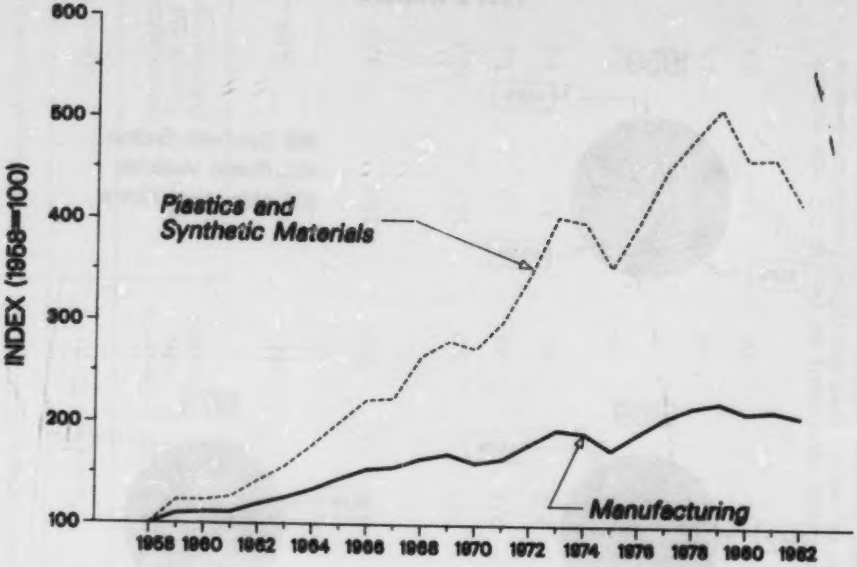
Real output of plastic materials and synthetics (SIC 282) grew rapidly since 1958, but there was a wide range of growth rates among specific industries in this group of petrochemicals. The rapid growth industries were noncellulosic fibers (SIC 2824) and plastic materials and resins (SIC 2821). Noncellulosic fibers, nylon and polyester, increased real products shipments at a compound annual rate of 12.2 percent in 1958-1980, far above the 7.2 percent growth rate of the total SIC 282 group and 3.6 percent growth rate for total manufacturing. It was the smallest industry in 1958, as measured in constant dollar shipments, but ballooned to the largest category in 1980. Plastic materials and resins also grew faster than the group average and total manufacturing; constant dollar shipments in SIC 2821 expanded at a compound annual rate of 7.4 percent in 1958 to 1980.

The slow growing industries in the SIC 282 group were cellulosic fibers (SIC 2823) and synthetic rubber (2822). Real output of cellulosic fibers, such as rayon and acetate, was virtually unchanged during this period as shown by a negligible growth rate of 0.1 percent in 1958 to 1980. The synthetic rubber industry faced a stagnating tire market in the second half of the 1970's caused by the shift to longer-lasting radial tires and smaller tires for down-sized cars. Constant dollar shipments of synthetic rubber grew only 3.2 percent a year during the 1958 to 1980 period, and slower than total manufacturing growth.

The composition of output among the three industries in the SIC 282 group shifted as a result of these differences in output growth rates (Figure 3). The share of man-made fibers expanded from 42 percent in 1959 to almost 46 percent in 1969 and 53 percent in 1979. In contrast, the output share of synthetic rubber plunged from 20 per

FIGURE 2

Constant-Dollar Shipments:
Plastics And Synthetic Materials Vs. Manufacturing



SOURCE: Bureau of the Census and Office of Business Analysis, U.S. Department of Commerce.

cent of total output in 1959 to 8 percent in 1979. Plastic materials and resins edged up in the 1960's to 41 percent, but dropped back to 39 percent in 1979, for a net gain of one percentage point since 1959.

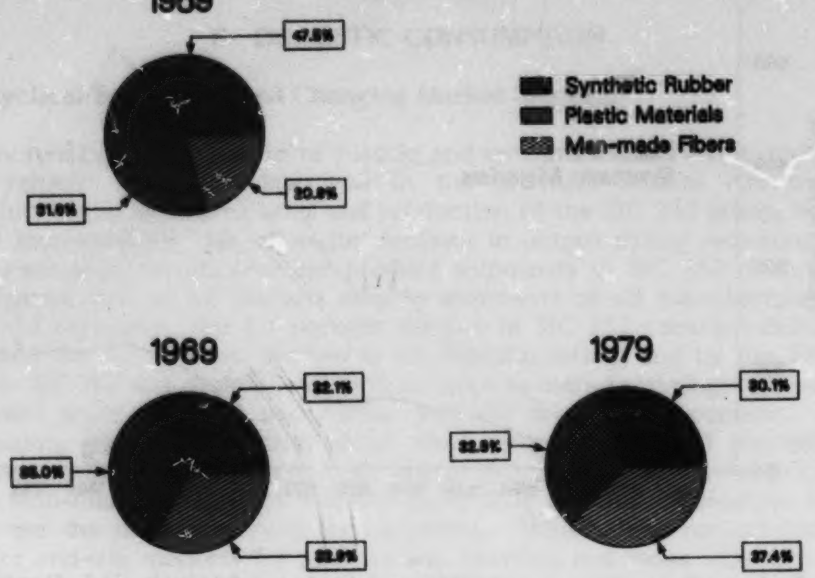
Technological Change And Substitution Vs. Growth In End Users' Final Demand

Much of the rapid growth in the SIC 282 group has been due to technological change and substitution, rather than growth in final demand for the major end-users of plastic materials and synthetics. For example, over the period 1972-1977, constant-dollar shipments for the SIC 282 group increased by $2,824 million; yet only $763 million or 27 percent of the increase was due to changes in final demand, while $2,061 million-- or 73 percent of the increase was due to technological change and substitution (Table2). Without technological change and substitution, the SIC 282 group would have grown at 1.5 percent per annum, a rate significantly below the all-manufacturing growth of 2.8 percent per annum. Instead, with technological change and substitution, the SIC 282 group grew at 5.3 percent per annum, a rate significantly above the all-manufacturing rate.

Among major end-users, the largest share of the total increase due to technological change and substitution — $2,061 million — was in the use of plastics in motor vehicle manufacture and auto repair services, which accounted for $423 million or 21 percent of the total increase. Innovations in the use of component housings, circuit boards and other plastic parts in the manufacture of electrical equipment, computers and office machines, and instruments accounted for another $349 million, or 17 percent of

FIGURE 3

SIC 282 Product Shipments:
Distribution Within Sub-Industries For 1959, 1969, and 1979
(1972 Dollars)



SOURCE: Bureau of the Census and Office of Business Analysis, U.S. Department of Commerce.

the increase. Innovations in the use of plastic materials in construction and plastic packaging in food accounted for 11 percent and 10 percent, respectively.

While final demand for motor vehicles and for electrical equipment, computers and office machines, and instruments increased significantly over the period 1972-77, most other end-users did not fare so well. Without innovations in the use of plastics and synthetic materials in construction and in food, SIC 282 constant-dollar shipments to these industries would have declined between 1972 and 1977. Rubber and miscellaneous plastics; wholesale and retail trade; and health, education and nonprofit services registered small increases in final demand relative to technological change and substitution. In textiles and apparel--the largest of the end-users--imports and product saturation limited growth in final demand and in technological change and substitution.

Future Is Bright For Plastics, But The Others...

Plastic materials and resins (SIC 2821) should continue to outperform the rest of the economy in the 1980's and through the middle of the next decade. The plastics industry shows no slowdown in expanding its range of market applications, and profits are sufficient to sustain a high level of investment spending. The cost of petroleum and natural gas feedstocks have eased in recent years and are expected to remain depressed through the 1980's. The phenomena, combined with new cost-saving production technology, should give plastics a competitive advantage in markets held by other materials, including glass, wood, metal, and paper. The opening of new markets for plastics in

TABLE 2

Sources Of Growth In Constant-Dollar Shipments, 1972-77 1/
Plastics And Synthetic Materials Industry

	Shipments (Millions 1972$)		Absolute Change, 1972-77			Average Annual Growth Rate, 1972-77		
				Change Due To:			Growth Due To:	
Shipments To: 2/	1972	1977	Total	Technological Change and Substitution	Change in Final Demand	Total	Technological Change and Substitution	Change in Final Demand
All Sectors	$9,684	$12,508	$2,824	$2,061	$763	5.3%	3.8%	1.5%
Major End Users:								
Motor Vehicle Repair	612	1,245	633	423	210	15.3	9.2	6.1
Electrical Equipment, Computer and Office Machines, Instruments	376	949	572	349	223	20.3	10.5	9.8
Construction	954	1,121	167	229	-62	3.3	4.6	-1.3
Food	438	585	147	213	-66	6.0	9.2	-3.2
Health, Education, and Nonprofit	257	491	234	180	54	13.8	9.9	3.9
Rubber & Misc. Plastics	776	951	139	132	7	3.4	3.2	0.4
Wholesale & Retail Trade	206	328	122	108	14	9.7	8.4	1.3
Textile and Apparel	2,695	2,795	100	21	79	0.7	0.2	0.5

1/ Calculated by applying 1972 total requirements (direct and indirect) input-output coefficients for the SIC 282 final demand categories from the 1977 input-output table. The result is an estimate of what shipments (direct and indirect) would have been to each end-user if only final demand had changed and input-output coefficients remained constant. These estimates are then compared to actual shipments -- which are equal to the product of 1977 total requirements input-output coefficients for each industry and the corresponding 1977 final demand categories -- and the residuals are assumed to be due to technological change and substitution. This assumption, however, only holds true for small changes in coefficients or final demand; and thus, these estimates should be regarded only as notional estimates.

2/ These estimates are based on Bureau of Economic Analysis Input-Output definitions. Thus, estimates in this table will vary from similar estimates found elsewhere in this report.

health care products, computers and electronics may offset some of the expected losses in U.S. export markets for "commodity" plastics to OPEC and other oil-rich nations. The U.S. industry has also maintained its dominance in specialty products. This combination of favorable factors can be translated into annual growth rates in real output of over 7 percent in the 1985-1995 period, according to projections by Data Resources, Inc.

In contrast to the robust performance projected for plastics, the two mature industries in the SIC 282 group--man-made fibers and synthetic rubber--face a mediocre future because imports limit growth in their end-use markets. Man-made fibers (SIC 2823 and 2824) are referred to as a mature industry because they have reached their market saturation point, 75 percent of the domestic fiber market. The growth in demand for man-made fibers will largely be determined by growth rates in end-use markets, and two major markets--textiles and apparel--have limited growth potential caused by import competition. Thus, man-made fibers are forecast to grow at about the same rate as the overall economy through the 1980's and mid-1990's, according to Data Resources, Inc. Synthetic rubber growth is expected to lag behind the overall economy because of strong imports of rubber products and because it is so closely linked to the automobile industry, and Data Resources expects autos to have below average growth resulting from strong import competition and adverse demographic trends.

C. FOREIGN COMPETITION

The exports of plastic materials and synthetics have substantially exceeded imports throughout the 1958 to 1981 period as shown in Figure 4 and Tables 3 and 4. In 1980, a record 14.6 percent of U.S. production was shipped abroad, compared with 9.1 percent in 1958; imports accounted for only 1.7 percent of new supply (shipments plus imports) in 1980, up slightly from 1.0 percent in 1958. Another measure of the sizeable U.S. trade surplus in the SIC 282 chemicals group is that the value of U.S. exports exceeded imports by a factor of 7.3 in 1981, although down from a ratio of 8.9 in 1958.

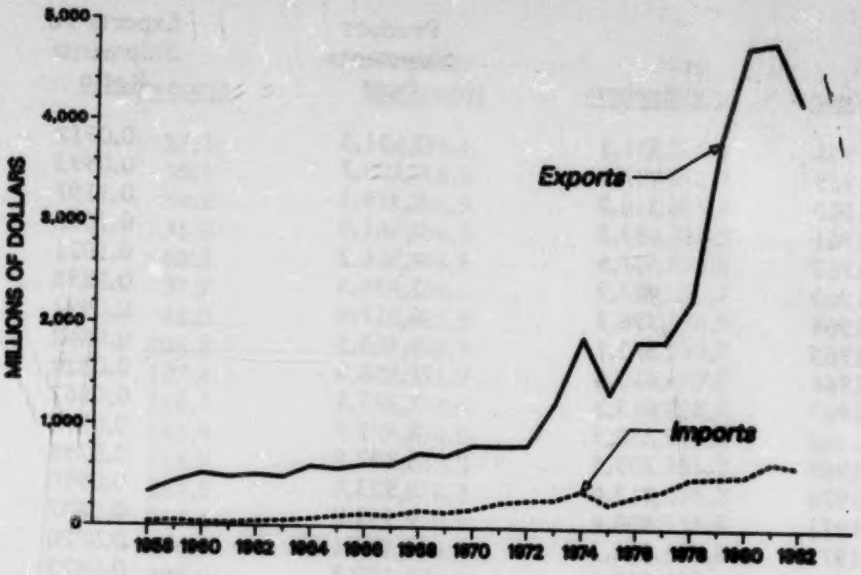
The U.S. competitive position was strong throughout the 1958-1980 period. At its lowest point in 1972, the exports to shipments ratio was 7.2 percent; the imports to new supply ratio reached a high of only 2.8 percent in 1971. Although the U.S. competitive position was good throughout the covered period, most measures of trade performance show that imports have been growing marginally faster than exports since the late 1950's. For example, U.S. exports of plastic materials and synthetics (SIC 282) increased at a compound annual rate of 12.3 percent from 1958 to 1981, but imports grew at an annual rate of 13.3 percent in the same period. (See Tables 3 and 4).

The relatively large U.S. trade surplus in plastic materials and synthetics can be attributed to three major factors. In this capital-intensive industry, with substantial economies of scale, the large size of the U.S. domestic market has enabled U.S. producers to build much larger, world-scale plants than their European competitors leading to significant cost-savings. The regulated U.S. energy market throughout most of the 1958 to 1981 period, especially for natural gas, led to lower feedstock costs for these petrochemical industries. The SIC 282 group of industries has also been characterized by a continual stream of new products and processes, especially for plastics and man-made fibers. The U.S. industry has also been a leader in developing new products and processes because of its emphasis on research and developments.

However, a new trend is developing in the mid-1980's involving a shift in the location of new production facilities toward the oil-rich nations of the world, such as Mexico, Canada, and Saudi Arabia. Most of the new facilities in less developed countries are joint ventures between multinational firms and foreign governments. For example,

FIGURE 4

Plastics And Synthetic Materials: Exports And Imports, 1958-82



SOURCE: International Trade Administration, U.S. Department of Commerce.

Exxon Corporation and Saudi Arabia are scheduled to complete a $1 billion low-density polyethylene plant in 1986; most of the output is designated for the European market. The cost advantages from access to virtually free natural gas feedstocks--natural gas was previously flared-off in the Middle East--can be significant. The Dow Chemical Corporation estimates that by 1986 Saudi Arabia could deliver linear low density polyethylene to Rotterdam at a price 20 percent below that which U.S. producers need to cover their costs.

In addition to the cost of feedstock, the cost of production is also determined by the size of production facilities because of the large economies of scale in the industry. Because of the enormous U.S. domestic market, the U.S. industry was able to build huge, world scale plants and compete effectively in world markets during the 1958-1971 period of U.S. oil import quotas, which raised domestic petroleum prices above world levels. In addition to economies of scale, the rate of capacity utilization also affects unit costs. While the oil rich countries have advantages from low feedstock costs and economies of scale, they are relying largely on exports and lack sizeable domestic markets. This strategy of supplying imports for distant markets has the risk of wide fluctuations in capacity utilization and unit costs if export demand is volatile, and trade barriers if domestic production in Europe and Asia is threatened by imports.

Another significant cost variable in world competition in the plastic materials and synthetics industry is the cost of capital. There are two developments in the 1980's which may cause problems for the U.S. industry. The high level of real U.S. interest rates relative to rates in Europe and Japan in recent years--estimated at 3 to 4 percentage points by the Council of Economic Advisers--increases the cost of U.S. production facilities financed by debt. However, other factors also determine the cost of

TABLE 3

Exports And Shipments Ratio, 1958-82
(Millions of Current Dollars)

Year	Exports	Product Shipments Base	Exports To Shipments Ratio
1958	331.2	3,631.5	0.0912
1959	437.4	4,403.7	0.0993
1960	516.2	4,314.1	0.1197
1961	483.2	4,461.9	0.1090
1962	507.8	4,976.2	0.1021
1963	487.9	5,434.5	0.0898
1964	596.3	6,017.4	0.0991
1965	573.1	6,805.5	0.0842
1966	615.4	7,466.9	0.0824
1967	615.2	7,272.4	0.0862
1968	730.5	8,478.7	0.0862
1969	709.5	8,892.9	0.0798
1970	812.4	8,923.4	0.0910
1971	808.4	9,662.0	0.0837
1972	816.3	11,330.1	0.0720
1973	1,237.4	14,189.8	0.0872
1974	1,885.3	17,638.2	0.1069
1975	1,333.8	16,829.7	0.0793
1976	1,846.7	20,350.5	0.0907
1977	1,851.0	23,153.1	0.0799
1978	2,268.3	26,039.2	0.0871
1979	3,837.0	30,928.6	0.1241
1980	4,768.5	32,631.5	0.1461
1981	4,815.5	36,423.1	0.1322
1982	4,215.1	30,540.0	0.1380

SOURCE: International Trade Administration, U.S. Department of Commerce.

capital, and tax incentives for investment, such as accelerated depreciation, may have offset the interest rate differential to some degree. The other capital cost problem facing U.S. producers of SIC 282 chemicals is the proliferation of production facilities in less developed countries built with government funds. Government subsidies lower the cost of capital; but this may be partly or wholly offset by the operating inefficiency of state-operated enterprises, especially in less developed countries characterized by shortages of skilled labor and managers.

The high level of U.S. interest rates relative to rates in other countries has been accompanied by another difficulty in the U.S. plastics and synthetics industry: the high level of the U.S. dollar relative to other currencies. The strength of the U.S. dollar has made imports attractive to end-users in the U.S. and U.S. exports un-attractive to end-users overseas.

A final cost factor influencing world competition is environmental control legislation. A significant portion of U.S. plastics and synthetic materials costs represent the costs of pollution abatement and control expenditures. Over the period 1975-80,

TABLE 4

Imports And New Supply, 1958-82
(Millions Of Current Dollars)

Year	Imports	Product Shipments	New Supply a/	Imports To New Supply Ratio
1958	37.3	3,539.1	3,576.4	0.0104
1959	50.1	4,318.4	4,368.5	0.0115
1960	34.1	4,246.9	4,281.0	0.0080
1961	31.6	4,354.9	4,386.5	0.0072
1962	48.8	4,846.8	4,895.6	0.0100
1963	57.7	5,194.0	5,251.7	0.0110
1964	78.0	5,685.9	5,736.9	0.0136
1965	106.8	6,432.9	6,539.7	0.0163
1966	127.8	7,051.9	7,179.7	0.0178
1967	116.1	6,772.6	6,888.7	0.0169
1968	165.4	7,834.0	7,999.4	0.0207
1969	148.9	8,239.3	8,388.2	0.0178
1970	184.0	8,074.2	8,258.2	0.0223
1971	248.4	8,710.4	8,958.8	0.0277
1972	274.5	9,913.3	10,187.8	0.0269
1973	285.0	12,327.4	12,612.4	0.0226
1974	372.6	15,839.7	16,212.3	0.0230
1975	240.9	15,127.6	15,368.5	0.0157
1976	325.6	18,767.5	19,093.1	0.0171
1977	381.3	21,973.0	22,354.3	0.0171
1978	502.9	24,901.4	25,404.3	0.0198
1979	513.7	29,819.9	30,333.6	0.0169
1980	529.4	31,447.7	31,977.1	0.0166
1981	662.4	35,161.6	35,824.0	0.0185
1982	617.4	29,480.8	30,098.2	0.0205

a/ New Supply = Imports + Product Shipments
SOURCE: International Trade Administration, U.S. Department of Commerce.

capital expenditures for pollution abatement and control averaged about 8 ½ percent of total capital expenditure in the U.S. plastics and synthetic materials industry; and in the future, the industry may have to increase pollution control expenditures in other areas, such as increased payments to the "Superfund." While some of our world competitors operate under environmental control constraints, others have few if any such constraints.

The adverse cost factors affecting the U.S. competitive position could be offset if the domestic producers introduce a large number of new product innovations. New products were the major source of industry growth in the 1970's and led to large trade surpluses. Because synthetic rubber and man-made fibers are mature industries and will mainly keep pace with the overall economy, only plastic materials and resins (SIC 2821) has the potential for rapid growth through technological change. In addition to product innovations, the U.S. plastics industry could maintain its competitive position if the world market continues to move in the direction of specialty plastics where the United States has a strong advantage from its vast resources of skilled scientists and engineers, and its lead in quality control of the production process.

A rapid slowdown in technological change and lack of new products in the plastics industry could turn the whole SIC 282 group of chemical industries into a mature industry, dependent on final demand in end-use markets for growth. A slow growth or stagnant industry is much more susceptable to injury from imports. If plastics, synthetic rubber, and man-made fibers becomes a "commodity" market, production will shift to the countries with the lowest feedstock and capital costs and the U.S. trade surplus in plastics and synthetic materials could disappear or become a deficit.

PART II

PRODUCTION TECHNOLOGY

AND

THE EVOLVING ANATOMY OF INPUTS AND INPUT PRICES

SINCE 1958

INTRODUCTION

PART I of this Report summarized and discussed the impressive array of major new process technologies which were developed by the U.S. plastics and synthetic materials industry since 1958 and which helped to make plastic and synthetic materials one of the most efficient of U.S. manufacturing industries. Interestingly, most of these cost-saving innovations were already being used by the industry by or before 1970. With few exceptions, the industry's post-1970 innovations have been modifications to and perfections of these pre-1970 innovations.

These technological innovations led to great savings in the industry's labor, materials, and capital requirements and contributed to the outstanding improvements in input productivity growth recorded by the industry over the entire 1958-80 interval, but especially between 1966 and 1974. These innovations also led to profound changes both in input structure and in the composition of the inputs used by the U.S. plastics and synthetic materials industry. For example, they have contributed to the industry's above average use of highly educated and technically trained personnel. 1/ They also led to a very rapid substitution of capital and materials for labor; and, in the days of cheap energy prior to 1974, they led to a rapid substitution of energy for labor, capital, and materials.

In the light of these process developments, PART II of this Report examines the evolution of the U.S. plastics and synthetic materials industry's input structure between 1958 and 1980. Using data developed by the Capital, Energy, and Productivity Studies Division of the Office of Business Analysis, sections A through D of Part II focus on each of the four major input categories -- capital, labor, energy, and materials -- to the production process.

The discussion contained in these four sections includes an analysis of historical trends in the price and quantity dimensions of each input as well as of changes in the quality or composition of each input. Frequently, these trends are compared both across industries and over time in terms of peak-to-peak business cycle periods, so that the influence of business cycles on the various economic measures examined can be controlled. 2/

1/ In the first instance, no doubt, the industry's highly innovative character was the direct effect of its well above average and growing use of highly educated and technically trained personnel. However, in the second instance, the installation and use of the new techniques and captial which embody the new innovations created an even greater demand for educated/technical workers relative to production workers.

2/ The years designated as output peaks for each industry discussed in the remainder of this study share three important characteristics: (a) they occur in close proximity to economy-wide periods of stagnant or declining economic growth; (b) they represent years of either peak or near-peak capacity utilization among the years 1958-80; and (c) they are followed by a year in which the industry's output growth declined dramatically. In most cases, these "output growth" peaks were also peaks in the traditional sense -- i.e., they were followed by a recession in the industry. The exceptions are 1959 and 1966 for all-manufacturing (the absolute output peak in all-manufacturing occurred in 1960, but no absolute peak occurred during the mid-sixties) and 1959 for steel (where the absolute peak occurred in 1960).

Finally, many of the important inferences mined in sections A through D are summarized in Section E. The discussion there focuses on important input substitution patterns that occurred in the U.S plastic and synthetic materials industry between 1958 and 1980. Section E also links these substitution patterns to the changes in relative prices paid by the plastics industry for its capital, labor, energy, and material inputs and to the basic changes in its technology that occurred since 1958. An analysis of the productivity and cost of production implications of the changes in the industry's technology and input structure will follow in PART III.

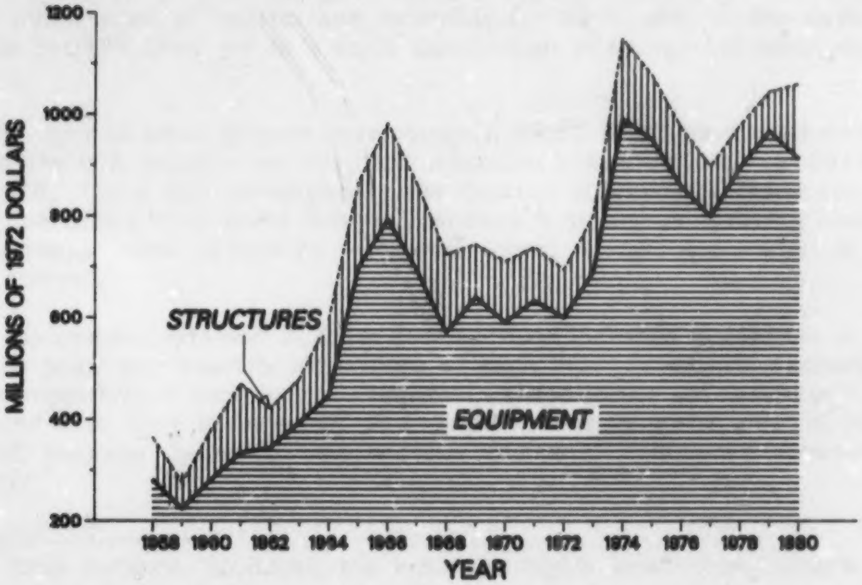
A. CAPITAL INPUTS

Measures of capital formation are widely considered to be the most important indicators of an industry's technical efficiency or productivity growth potential. This section presents and examines important indicators of capital formation in the U.S. plastics and synthetic materials industry. Each measure discussed below presents a different view of the industry's capital formation. The presentation progresses from measures of real gross plant and equipment investment, to real net investment, to real net productive investment (net of pollution abatement expenditures), and to real net productive capital stocks of plant and equipment. The quality of these stocks, their utilization rate; and the growth in real capital per worker are also examined.

A.1 Capital Investment and Capital Stocks

FIGURE 5

Gross Investment In Plant And Equipment, 1958-80
(Millions Of 1972 Dollars)



SOURCE: Office of Business Analysis, U.S. Department of Commerce.

Real Gross Investment Tripled Between 1958 And 1980;...

Real (1972 dollars) gross investment in structures and equipment by the plastics and synthetic materials industry (see Figure 5) tripled in the 23 year period from 1958 to 1980; rising from $363 million in 1958 to $1,060 million in 1980. This increase did not occur as a smooth trend over the period but rather closely followed major business cycles. The period of most rapid growth in investment was 1959 to 1966 when real investment increased from $363 million to $981 million -- an annual rate of increase of 21 percent. This period was followed by a slowdown in capital expenditures to an average level of $700 million between 1968 and 1972. A brief but strong spurt in 1973-74 sent annual capital expenditures soaring to over $1.1 billion in 1974. This recovery, however, was shortlived because of the oil price increases and the recession of the mid 1970's. As a result, the industry's annual capital spending rate fell by over $200 million to a level of $900 million in 1977, before returning to the $1.1 billion level in 1980.

Moreover, after 1966, the use of investment funds shifted away from structures to equipment. Equipment is usually associated with enhancing or maintaining existing plant capacity whereas investment in structures is usually related to adding to capacity. The large increase in investment spending between the industry's 1959 and 1966 output peaks was distributed proportionally between plant and equipment; both increased by over two and one-half times. However, between the 1966 and 1979 output peaks, annual real investment in equipment increased by only 8 percent and the rate of real investment in plant actually fell by nearly one-half. Thus, by the late 1970's equipment spending averaged 94 percent of all capital expenditures, compared to about 80 percent during 1959-66.

Investment in structures over the period follows a more pronounced cyclical pattern than equipment. Peak levels of real investment in structures of $136, $190 and $158 million (1972 dollars) occurred in 1961, 66, and 74 respectively. However, after 1966, investment in new plant facilities trended downward, falling to roughly 50 percent of the 1966 peak by 1979. The peak year 1974 brought only a brief respite from this trend for it was quickly followed by the cutback in capital expenditures induced by the 1974-75 recession.

...And Net Capital Stock Also Increased 300 Percent;...

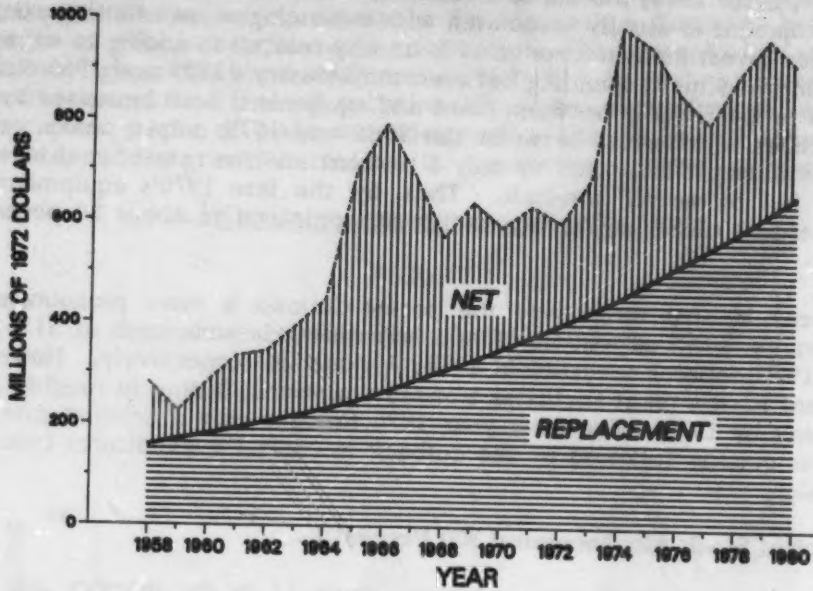
The real (1972 dollars) net equipment stock 1/ in the plastics and synthetics industry increased by more than 300 percent between 1958 and 1980; rising from $2.7 billion in 1958 to nearly $9 billion in 1980. The real (1972 dollars) net plant stock followed a similar pattern; increasing from $1.1 billion to $2.7 billion between 1958 and 1980 -- an increase of more than 150 percent. During the sharp growth period of 1959-66, the real equipment stock increased at an average annual rate of nearly 8 percent and the real plant stock increased at an average annual rate of 7 percent.

Capital expenditures are used for two purposes: first, to replace assets which have worn out or have become less productive through use; and second, to increase capacity. The impressive growth in plant and equipment facilities in the plastics industry can be attributed to the sustained levels of gross investment which exceeded the amount necessary to maintain the existing capacity. In 1959, real equipment replacement needs were $170 million or 75 percent of total equipment expenditures (see Figure 6). This was the amount needed to replace assets that were discarded and also replace capacity lost due to wear and tear on existing machinery. In contrast, by 1966, real replacement needs had risen to $265 million but total equipment spending was $792 million. The $528 million difference represents new additions to the equipment stock. By 1980, replacement needs had risen to $658 million but the industry still added one-quarter billion dollars to the value of the net equipment stock.

1/ Gross investment is defined as total new capital expenditures; net investment is that portion of gross investment devoted to increasing the capital stock. Net investment may be negative in years where gross investment is smaller than the amount required to replace assets which are wearing out. The net capital stock is defined as all capital on hand adjusted to account for assets which have worn out or lost some of their original productiveness through use.

FIGURE 6

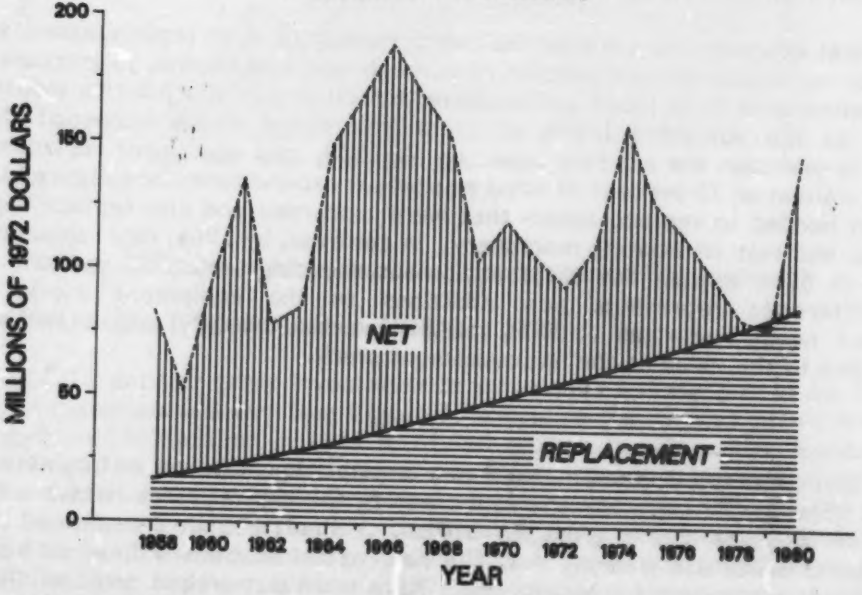
Net And Replacement Equipment Investment, 1958-80
(Millions of 1972 dollars)



SOURCE: Office of Business Analysis, U.S. Department of Commerce.

FIGURE 7

Net And Replacement Investment In Structures, 1958-80
(Millions of 1972 dollars)



SOURCE: Office of Business Analysis, U.S. Department of Commerce.

During the 1960's, most expenditures for structures by plastics manufactures went to expand capacity. Between 1958 and 1966, less than 25 percent of plant expenditures were used on average to replace older facilities (see Figure 7). The remaining 75 percent was added to capacity. However, the trend changed dramatically following the 1966 peak investment year. For example, total real (1972 dollars) plant expenditures fell to $94.3 million in 1972 but replacement needs steadily rose to $56.8 million, leaving 40 percent of 1972 plant expenditures for expansion. Following a brief resurgence of spending for structures in 1974, real plant spending fell steadily through 1978 when new additions to the plastics industry plant capacity were only $4 million. Structures replacement investment in 1978 totaled $82.3 million or 95 percent of total investment in structures.

...But, The Proportion Of Real Investment Spent For Pollution Control Capital More Than Doubled Between 1967 And 1977; ...

The real net capital stock trends cited above include capital assets acquired for all purposes. Since 1967, though, a significant and an increasing share of capital expenditures has been devoted to acquiring pollution control apparatus. These assets range from devices to remove particulates and polluting gases from smokestack emmissions, to water purification and cooling facilities, to solid waste disposal. Pollution control assets are usually not employed directly in the production process. Consequently, the total capital stock measures which include these devices may not be useful as an indicator of an industry's productive ability unless the value of assets not used for production are removed.

Real capital expenditures for pollution control devices increased steadily from a level of $39 million in 1967 to a peak of $102 million (1972 dollars) in 1977. The former value was only 4.6 percent of total real investment by the plastic and synthetic materials industry in 1967; but the latter value was nearly 12 percent of total investment in 1977. By 1980, real pollution control investment expenditures had tapered slowly back to $58 million or 5.4 percent of all real capital investment, as many of the regulations and waste disposal requirements had been met.

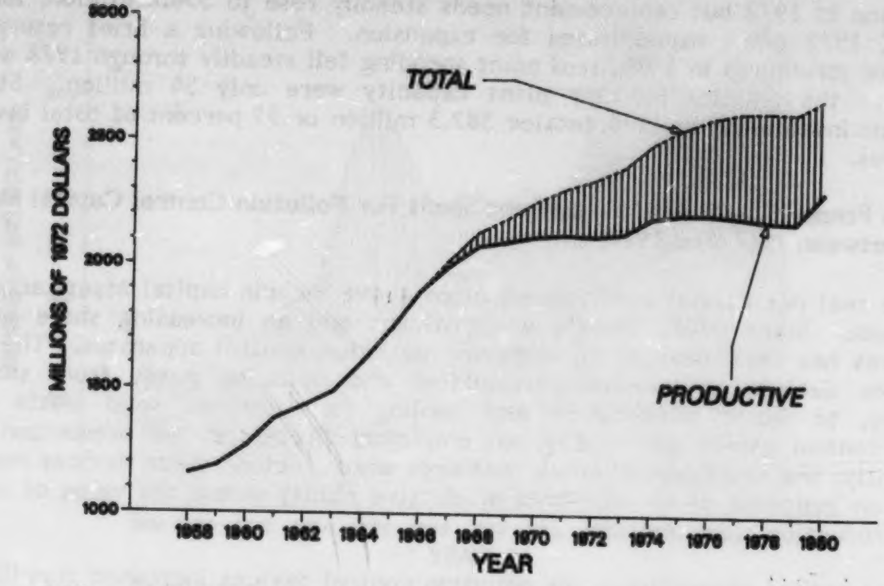
Most pollution control apparatus purchased prior to 1977 was intended for water pollution control. These expenditures averaged 60 percent of total pollution abatement capital expenditures. Many of these expenses were incurred to meet deadlines imposed by the Clean Water Act of 1972 which required installation of secondary wastewater treatment facilities by mid-1977. Thereafter, expenditures for water pollution control devices fell to 35 percent of all pollution control investment by 1979. Most of the remaining pollution control investment went for air pollution control devices. Expenditures for solid waste disposal were usually less than five percent of total pollution abatement capital expenditures. However, increased public awareness of problems associated with hazardous waste disposal has increased the need for capital to safely dispose these contaminants. Thus, by 1980, expenditures for solid waste disposal had increased to $8.3 million or 7 percent of the total. Events since 1980 indicate solid waste disposal will remain a concern and will continue to require high levels of capital investment, as technologies are developed to cleanly dispose of solid pollutants.

...Helping To Slow The Rate Of Growth In Productive Capital During The 1970's.

Mandated pollution control investment had a major effect on the industry's ability to invest in new productive plants and structures. These expenditures are closely tied to water pollution control facilities which are usually structures. In real terms, investment in structures for pollution control consumed an average of 34 percent of total structures

FIGURE 8

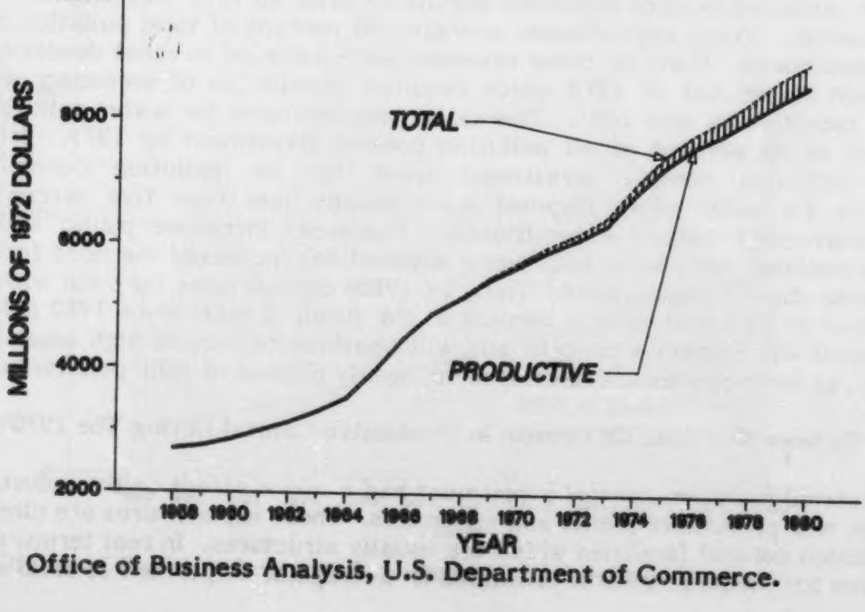
Stocks Of Real Net Plant, 1958-80: Total, Productive, And Pollution Abatement (Millions Of 1972 Dollars)



SOURCE: Office of Business Analysis, U.S. Department of Commerce.

FIGURE 9

Stocks Of Real Net Equipment, 1958-80: Total, Productive, And Pollution Abatement (Millions Of 1972 Dollars)



SOURCE: Office of Business Analysis, U.S. Department of Commerce.

spending between 1967 and 1980, reaching a peak of 46 percent in 1972. Real expenditures in pollution abatement capital grew from $26.4 million in 1967 to a peak level of $48 million in 1970. Annual investment remained in the $45-50 million range through 1976.

After 1976, investment in pollution abatement plant fell sharply to only $15.9 million in 1980. However, plant investment for all purposes also fell during this same period. The net effect was to reduce the amount of investment in new productive plant in the industry by 26 percent. Moreover,the net plant stock, excluding pollution control apparatus, actually fell in four years between 1970 and 1979 and only grew marginally during the remaining years in the period. By 1980, the real net stock of pollution abatement plant was nearly $500 million. After adjusting the total real net plant stock to exclude pollution control structures, we find (see Figure 8) that the peak-to-peak productive plant capacity of the plastics industry grew only three percent during the 1970's; rising from $2,096 million (1972 dollars) in 1969 to $2,169 in 1979.

By contrast, real investment in pollution control equipment by the plastics and synthetic materials industry had a much smaller effect on the industry's ability to invest in new productive equipment. These expenditures averaged less than 5 percent of total equipment spending during the 1967-80 period, reaching a high of $65.9 million or 7.6 percent of all equipment spending in 1978. Finally, while the real net stock of pollution control equipment grew to nearly $300 million by 1979, this represented only a small portion of the industry's $8.6 billion total real equipment stock (Figure 9).

A.2 Capital Quality

The Size Of The Capital Stock Is Only Part Of The Story: Quality Of The Capital Stock.

The size of the real net productive stock of capital in the plastics industry constitutes an important indicator of its productive capacity and productivity potential. However, the age of that stock is, perhaps, a better indicator of the overall level of the technological capability embedded in this capital stock. Just as a more educated work force is more productive, a newer, more technologically advanced capital stock is more productive.

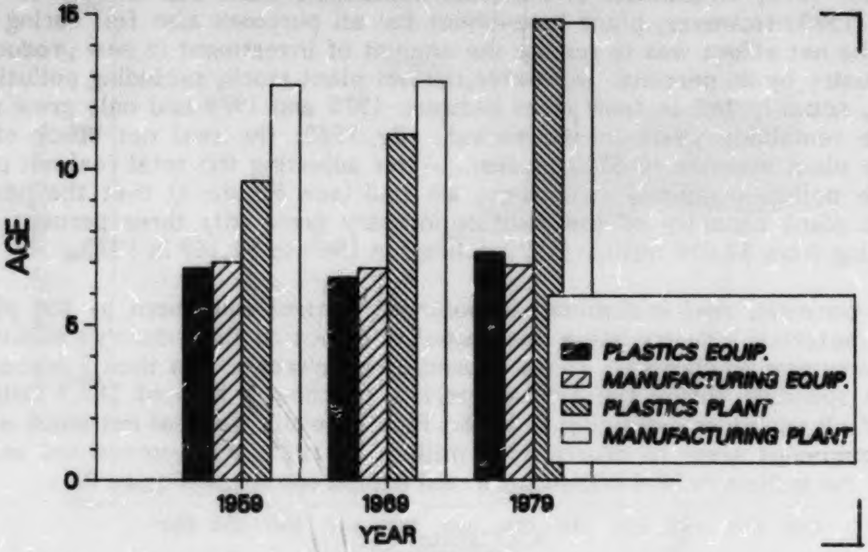
Plastics Began The 1958-80 Era With A Larger Proportion Of New Capital Than Found In All-Manufacturing;...

The years immediately following World War II found the capital stock in the plastics and synthetic materials industry in excellent condition. The average ages of the plant and equipment real gross stocks were 6 and 4.7 years respectively and more than 50 percent of the productive facilities were less than five years old. Much of this condition can be attributed to the rapid growth in demand for goods produced by the industry's new plastic technology during and after the war.

By 1959, the average age of the productive plant stock had increased to 9.6 years. By contrast, the average age of plant in manufacturing industries overall stood at 12.7 years, over 3 years older. The average age of the equipment gross stock also increased to 6.8 years, slightly newer than the average age of 7 years for the equipment stock in overall manufacturing (see Figure 10). Nevertheless, the plastic industry continued to operate with newer capital — one-third of all structures and nearly 42 percent of all equipment assets were less than five years old in 1959. By contrast, only one-quarter of the all-manufacturing plant stock and 40 percent of the all-manufacturing equipment stock were new in 1959 (see Figure 11).

FIGURE 10

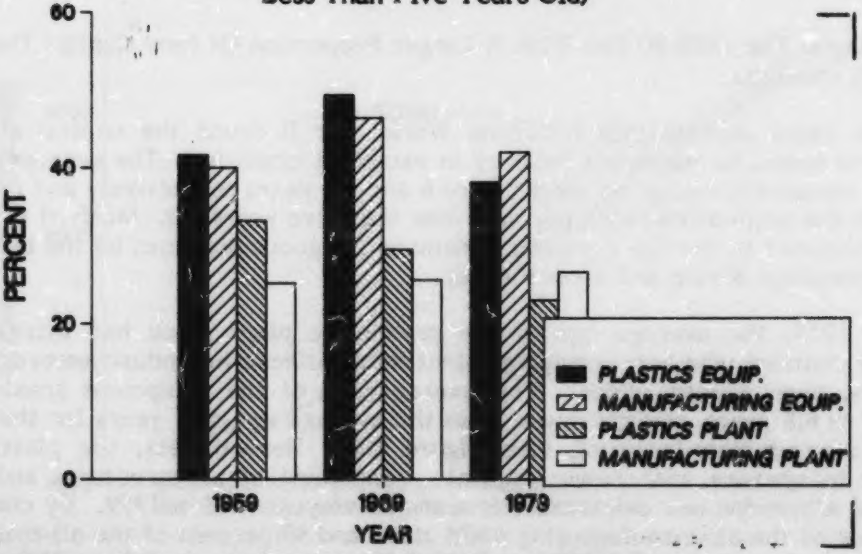
The Average Age Of The Gross Productive Capital Stock At Selected Output Peaks: 1959, 1969, And 1979 Plastics Vs. All-Manufacturing



SOURCE: Office of Business Analysis, U.S. Department of Commerce.

FIGURE 11

The Newness Of The Gross Pollution Capital Stock At Selected Output Peaks: 1959, 1969, And 1979 Plastics Vs. All-Manufacturing (Percent Of Total Gross Productive Stock Less Than Five Years Old)



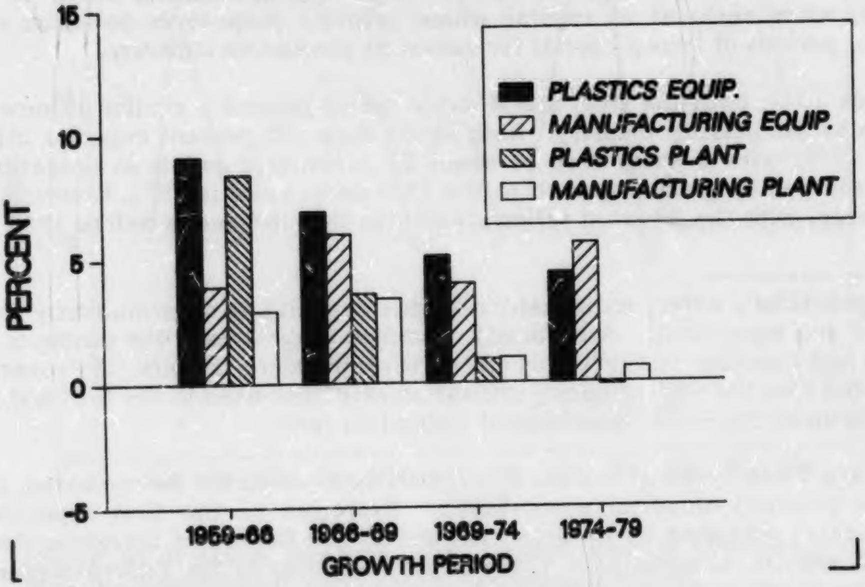
SOURCE: Office of Business Analysis, U.S. Department of Commerce.

...And Plastic's Plant And Equipment Became Even Newer In The 1960's;...

The rate of investment by plastics during the 1960's ran well ahead of that in all-manufacturing (see Figure 12). This strong investment growth served to reduce the average age of plastic's productive equipment stock to 6.4 years and to increase the portion of equipment stocks less than five years old to nearly 50 percent by 1968. Meanwhile, the average age of the productive plant stock increased to 10.4 years in 1968, but the proportion of it less than five years old also increased to more than 35 percent. Figures 10 and 11 demonstrate that the productive stocks of equipment and plant used by the plastics industry remained considerably newer than the average for all-manufacturing throughout the 1959-69 period, reflecting the above average rates of capital formation in this industry.

FIGURE 12

The Growth In Productive Plant And Equipment Stocks Over Comparable Selected Intervals: Plastics Vs. All-Manufacturing (Average Annual Percent Change)



SOURCE: U.S Department of Commerce, Office of Business Analysis.

... But Began To Age In The 1970's.

Starting in 1969, the situation reversed. By 1979, the average age of the plastics industry's productive plant stock had increased to 14.8 years, nearly 5 years older than in 1968. This was still lower than the average age for all-manufacturing but, perhaps more importantly, the proportion of new plant assets had plummeted to just 13 percent in plastics, whereas over 18 percent of all manufacturing plant stock was considered new. This trend reflects the reduced rate of total plant investment by the plastics industry after 1968 and the increased rate of spending for pollution control plant which is not included in measures of the productive stock.

The growth in the average age of the stock of productive equipment in the plastics industry followed a similar although less dramatic pattern, with a gradual increase in the average age to 7.3 years by 1979. Moreover, the percent of the equipment stock that was new fell dramatically by 12 percentage points from 50 percent in 1968 to 38 percent in 1979. By contrast, during the same period, manufacturing industries overall invested in sufficient quantities to reduce the average age of their equipment slightly from 7.1 years in 1966 to 6.9 years in 1969 and to maintain the new equipment proportion at the 1966 level of 42 percent.

A.3 Capacity Utilization

A third important dimension of the industry's capital stock is its rate of utilization. This measure serves as an indicator of how effectively the industry is using its existing stocks of plant and equipment over time. It also serves as an indicator of when expansion of productive capital is necessary to satisfy increased demand. Figure 13 presents a new measure of capacity utilization developed by the OBA. 2/ For comparison purposes, measures developed by Wharton EFA are also presented. 3/ Both the OBA and Wharton series are derived using measures of industrial output to determine an industry's maximum productive capacity. Unlike the Wharton series, however, the OBA utilization rates are also based on measures of the industry's net capital stock of plant and equipment, after removal of capital whose primary purpose is pollution control, to account for periods of strong capital formation on productive capacity.

Since 1972, both the OBA and Wharton series present a similar picture of capital utilization by the plastics industry. Both series show 100 percent capacity utilization in 1973 and 1979, with a sharp drop of about 25 percentage points in operating rates in 1974-75, followed by gradual growth to the 1979 peak. Prior to 1972, however, these two series diverge, with the Wharton series lower than the OBA series before 1965 and higher

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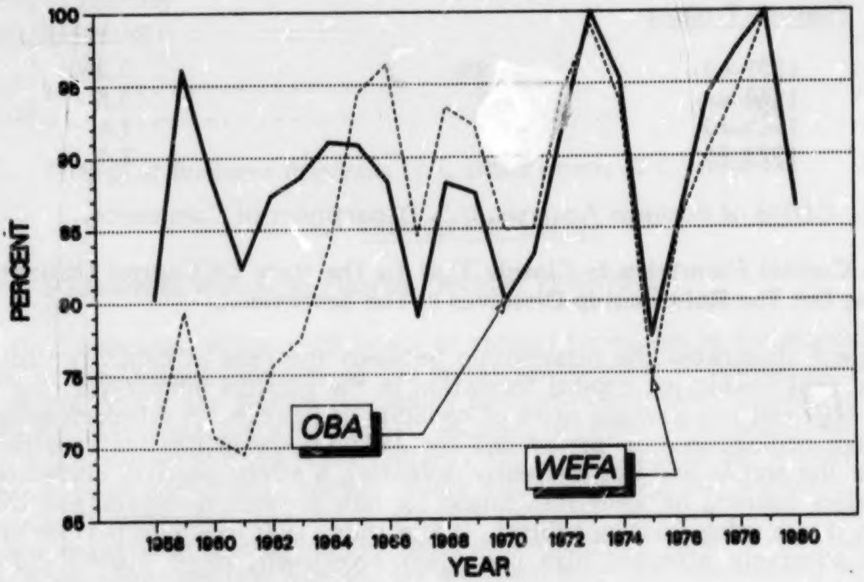
2/ As a practical matter, an industry's output capacity is determined by its stock of fixed plant and equipment. Accordingly, common usage treats the concepts of capital utilization and capacity utilization as essentially equivalent notions. Moreover, it can be demonstrated that the OBA capacity utilization rate (discussed in the text and footnote 6 below) is formally equivalent to a capital utilization rate.

3/ There are three types of capital utilization rate measures: survey-based, production based, and production/capital stock-based. Examples of the first type include the utilization rates published by McGraw-Hill and by the Bureau of Economic Analysis and the Census; and, to an some extent, the series published by the Federal Reserve Board. The Wharton series is an example of the second type, and the OBA series of the third type. Concerning survey-based measures, Frank Deleeuw of the Bureau of Economic Analysis noted that, compared with either production-based or production/capital stock-based utilization rates: "Survey-based measures of utilization displayed a cyclical sluggishness that has been disappointing and puzzling ... survey-based utilization rates imply an implausible degree of short-run sensitivity of capacity to the rate of growth of output." DeLeeuw analyzed several suggested reasons for this phenomenon and concluded that overreporting of "no change" and the use of labor rather than output to measure capacity utilization by a large percentage of respondents explained a "substantial fraction of the differences in amplitude of swing between survey-based and production-based measures of capacity utilization. Production-based measures may miss slowdowns or speedups in capacity growth due to fluctuations and trends in investment when compared to production/captial stock-based measures. As a result, such measures are likely to fall more in contractions and rise more in expansions than capital stock-based measures and their levels may be above or below capital-based measures for extended periods of time.

from 1965 to 1971. Much of the difference between the two series during these years is explained by differences in how industry redefinitions, which occurred in 1972, were treated by the respective agencies. However, part of the difference during the 1960's is also explained by the large increase in productive capital in the plastics industry, which is captured in the OBA series but not in the Wharton series. The OBA data show a very high 96 percent rate of capacity utilization in 1959; followed by a sharp falloff to about 82 percent in 1961; and a subsequent rapid expansion to a more than 90 percent rate of utilization in 1964-65. During the 1967-70 period, the utilization rate ranged from a high of 88 percent in 1968 to a low of 80 percent in 1971. This was followed by the strong growth spurt which led to the 1973 utilization peak.

FIGURE 13

Capacity Utilization Rates, 1958-80
OBA And Wharton



SOURCE: Office of Business Analysis, U.S. Department of Commerce (OBA); and Wharton Econometric Forecasting Associates (WEFA).

Productivity Growth Patterns Mirror Growth Patterns In Capital Utilization Rate.

The strong linkage between capital utilization and the productive efficiency of the plastics and synthetic materials industry is shown in Table 5, which compares changes in the industry's capacity utilization and labor productivity during four periods of expansion and four periods of contraction in the utilization rate. Without exception, the data show that the periods of most rapid average annual growth in productivity are also the periods of most rapid average annual increase in capital utilization. Moreover, the data show that the converse tends to be true; periods of least growth in productivity correspond to periods of greatest average decline in the capital utilization rate, with the exception of the 1973-75 period.

TABLE 5

Comparison Of Growth In Capacity Utilization And Labor Productivity During Periods Of Expansion And Contraction In Capacity Utilization
(Average Annual Percent Change)

Period	Capacity Utilization	Labor Productivity
Trough-to-Peak:		
1961-64	3.4%	5.0%
1967-68	11.9	11.1
1970-73	7.7	11.1
1975-79	6.6	7.0
Peak-to-Trough:		
1959-60	-7.9%	0.2%
1964-67	-4.5	3.8
1968-70	-4.7	1.4
1973-75	-11.7	2.4

SOURCE: Office of Business Analysis, U.S. Department of Commerce.

Growth In Capital Formation Is Closely Tied To The Rate Of Capital Utilization During The Sixties; But The Relationship Dissolves In The Seventies...

Table 6 illustrates the relationship between the rate of capacity utilization and the rate of real productive capital formation in the plastics industry, during multi-year periods of high and low average rates of capacity utilization. A comparison between the 1962-66 high utilization rate period and the 1967-71 low utilization rate period shows that during the sixties and into the early seventies, a strong positive correlation existed in the plastics industry between its demand for new productive capital and the intensity with which it was using existing capital. It also shows that extended periods of depressed utilization adversely affected high risk plant investment more than it did equipment investment.

After 1971, however, the relationship weakens. For example, a comparison between the high utilization rate 1972-74 period and the low utilization rate 1975-76 period shows that, although the industry significantly reduced its rate of new plant formation, it nevertheless invested in new equipment during the 1975-76 recession at about the same rate as it did during the 1972-74 expansion, possibly in an effort to reduce its energy costs by investing in energy-saving equipment (see PART II Section E). Moreover, an examination of the 1977-79 period indicates a collapse of the historical relationship between the industry's intensity of use of its fixed capital and its demand for new capital. Thus, despite all-time high average utilization rates, the industry ceased new capital formation in the case of plant and significantly reduced its rate of acquisition in the case of equipment (Table 6). However, as we will see in Section B which follows, this result coincides perfectly with a momentous development in the financial performance of the plastics and synthetic materials industry -- 1977-79 saw the cost of capital to the industry exceed its rate of return on capital for the first time during the 1958-80 period.

TABLE 6

Comparison Between Average Rates Of Growth In Net Productive Capital Stock And Average Capacity Utilization Rates During High And Low Rate-Of-Capacity-Utilization Intervals

		Average Annual Growth Rates Of Real Net Productive Capital Stock:	
High Average Capacity Utilization Intervals:	Average Capacity Utilization Rate	Plant	Equipment
1962-66	89.2	6.6%	8.6%
1972-74	95.8	1.1	5.0
1977-79	97.2	-0.5	3.2
Low Average Capacity Utilization Intervals:			
1967-71	83.6	2.3	5.5
1975-76	81.7	0.4	5.4

SOURCE: Office of Business Analysis, U.S. Department of Commerce.

A.4 Capital Per Worker

Capital Per Production Worker In Plastics Doubled 1959-79;...

A final indicator of the sufficiency of capital formation in the plastics industry is a measure of the capital intensity of the production process — capital per worker. The real net capital stock per worker (excluding pollution abatement capital) in the plastics and synthetic materials industry almost doubled between 1958 and 1980; rising from $36,875 per worker to $71,855 (1972 dollars). Moreover, capital per worker increased in nearly every year during this period. These figures include all workers in the in the industry — both production and nonproduction workers. However, over two thirds of all workers are engaged in production and most of the capital stock is used for production purposes. When nonproduction workers are excluded from the calculation, we find a more dramatic increase in capital per worker. Real productive capital per production worker increased by over $50,000, rising from $52,200 in 1958 to nearly $105 thousand in 1980. Figure 14 illustrates the growth in the level of real capital per production worker over the succession of major output peaks between 1959 and 1979.

...And Increased From Three To Four Times The Level Found In All-Manufacturing;...

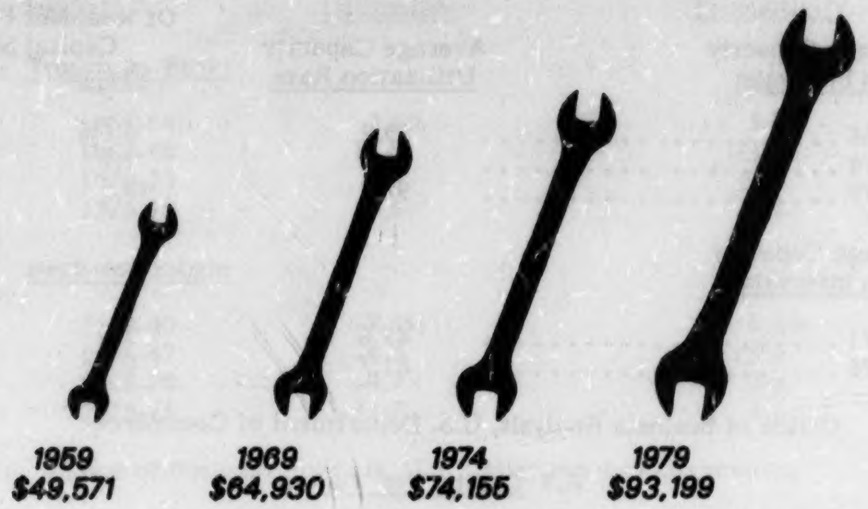
In 1959, production workers in plastics were using over three times the amount of capital their counterparts were using in other manufacturing industries -- $15,400 in all-manufacturing versus $49,571 in plastics. By 1979, the gap had widened to nearly four times, with the average plastics industry worker using more than $93,000 in productive capital assets while the average manufacturing production worker was using $24,400.

...But Capital Per Production Worker Grew For Different Reasons After 1974.

The real net capital stock per production worker increased by over $24,000 between 1959 and 1974 and by over $19,000 between 1974 and 1979. Much of this growth can be attributed to the stronger than average rate of capital accumulation in the

FIGURE 14

Real Productive Capital Per Production Worker
At Selected Real Output Peaks, 1959-79
(1972 Dollars)



SOURCE: Office of Business Analysis, U.S. Department of Commerce.

plastics industry, which showed an increase in its real net productive capital stock of nearly 300 percent between 1958 and 1980 versus a doubling in all- manufacturing. Nevertheless, two very distinct periods characterize employment and capital stock growth in the plastics industry -- 1958-74 and 1974-79.

During the 1958-74 period, the total net productive capital stock more than doubled; growing at an annual average rate of 5.9 percent. The number of production workers also increased but at a growth rate approximately one-half the productive capital stock growth rate. The 1974-79 period, by contrast, showed a marked slowing of capital accumulation to an annual average growth rate of 3.1 percent. Also, 1974 marked a peak year for production worker employment in the plastics industry. Between 1974 and 1979, production worker employment fell by nearly 9,000 workers, from 121.8 thousand in 1974 to 112.9 thousand in 1979. Consequently, unlike the 1958-74 period, much of the apparent increase in capital per worker between 1974 and 1979 was caused by a decrease in the number of production workers; not by growth in the capital stock (See PART II: Section C for a detailed discussion of trends in plastic industry employment).

Summary

By manufacturing standards, the plastics industry was relatively new in 1958. Much of the technology and most of the industrial facilities in place were developed following World War II. Between the output peaks of 1959 and 1969, the plastics industry invested heavily in capital equipment and plant which embodied the latest in technical innovations. Its stock of real net productive capital increased more than 91 percent, compared with just over 32 percent for manufacturing industries overall. As a result, the quality of the productive equipment stock in the U.S. plastics and synthetic materials industry (indicated by the proportion of capital less than 5-years old) increased from 41.6 to 49.3 percent. By comparison, the all-manufacturing productive equipment stock quality improved from 40.0 to 46.4 percent. Plant investment in plastics and manufacturing industries overall was sufficient to maintain the quality of the productive structures stock at the 1959 levels; one-third of plastics industry structures were new and one-quarter of all manufacturing structures were new. Meanwhile, the amount of real capital per production worker in plastics increased 31 percent between 1959 and 1969, compared with a less than 21 percent increase in all-manufacturing. This widened the gap of real capital per production worker in plastics from 3.2 to 3.5 times the amount found in all-manufacturing.

Since 1969, however, the industry's rate of net real productive capital formation has slowed considerably, increasing at an average annual rate of 4 percent between the 1969 and 1974 output peaks and 3.4 percent between the 1974 and 1979 peaks. These increases compare with corresponding increases of 2.5 percent and 3.5 percent respectively in manufacturing overall during comparable peak-to-peak periods of 1969-73 and 1973-79. As a consequence, the big pre-1970 gap between the quality of the productive capital stocks in plastics versus all-manufacturing closed and reversed. By 1979, the percent of new structures had plummeted to 13 percent in the plastics industry compared to 18 percent of structures in manufacturing industries overall. The portion of the plastic industry's equipment stock that was new also fell dramatically to 38.1 percent in 1979 versus a small decrease of four percentage points in the new equipment stock of all manufacturing industries.

Much of this post - 1969 turnabout in capital formation in the U.S. plastics and synthetic materials industry stems from a number of factors caused by changes in the business cycle, the maturing of the plastics industry, and the rapid growth of energy prices since 1973. These include: a 50 percent decline in the rate of growth in output demand for the industry's products (see PART I: Section B); the increased competitiveness of Japanese and European producers; a sharp increase in the industry's cost of capital; and a sharp decline in its real rate of return on invested capital (see PART II: Section B). A final contributing factor was the rapid growth in government mandated expenditures for pollution control between 1967 and 1977.

B. RATES OF RETURN AND COSTS OF CAPITAL

Throughout the 1958-80 period, the plastics and synthetic materials industry has consistently maintained a stock of highly productive physical capital. Operating efficiencies and technological advances have also enabled the industry to acquire and retain the confidence of the capital markets. This section examines the history of several of the U.S. plastics and synthetic materials industry's financial health indicators, including its rates of return on capital, costs of capital, interest and debt burden, and sources and uses of funds. It also compares the industry's performance in these areas with that of manufacturing industries as a whole.

B.1 Rates of Return 1/

Nominal Rate Of Return On Capital In The Plastics Industry Declined During The Sixties, Then Staged Modest Recovery In The Seventies

Figure 15 compares the ratio of earnings before interest and taxes to the book value of capital stock in the plastics industry with that of all-manufacturing during the 1958-80 period. We see there that the nominal rate of return on capital in the plastics industry fell from its maximum of 21.6 percent in 1959 to its minimum of 9.3 percent in 1970-- over 12 percentage points (see Figure 15).

This declining trend was reversed in 1971 and the industry's rate of return rose to 16.2 percent in 1974. However, following the 1973-74 energy price shock the industry's rate of return fell to 12.3 percent in 1975. Thereafter, it increased in a somewhat erratic manner to 15.8 percent in 1979, as the industry's rate of capacity utilization steadily increased from 77.6 percent in 1975 to 100 percent in 1979 (see PART II: Section A.3).

The dashed line in Figure 15 represents a trend curve fitted to the plastics industry's rate of return during the 1958-80 period. This curve points out both the direction of growth in the industry's rate of return and the relative growth rates during the sixties and seventies respectively.

Since 1965, Nominal Rate Of Return On Capital In Plastics Industry Lagged The All-Manufacturing Rate, But...

As shown in Figure 15, the plastics industry generated a rate of return on capital which averaged more than 2 percentage points higher than that of all-manufacturing during the 1958-64 period. The rate of return on capital in all-manufacturing first

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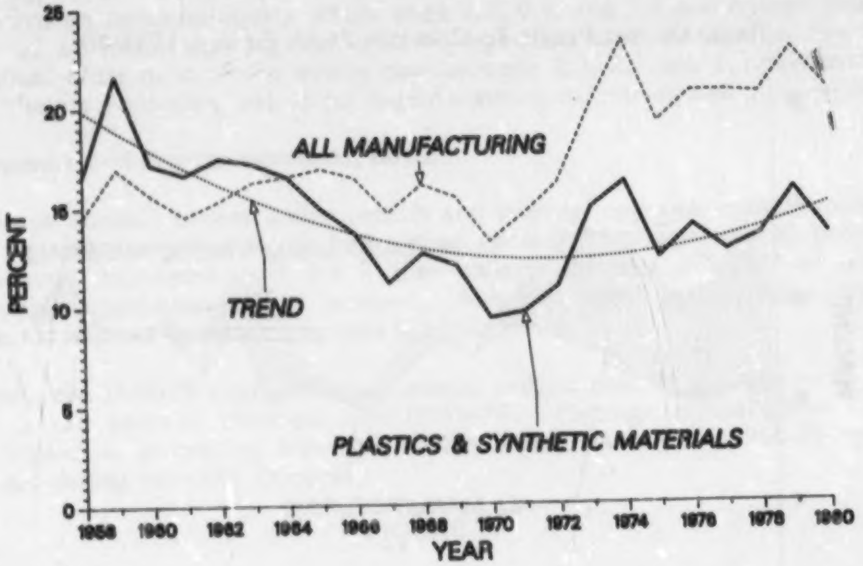
1/ The rate of return and other financial statistics reported in this section are based on a sample of 26 companies taken from Standard and Poor's Compustat. The Office of Business Analysis adjusted Compustat's consolidated company - level profit and capital stocks data to an industry - level basis prior to computing the rate of return on capital. This adjustment was performed in two steps: (1) any company with less than 20 percent of its shipments in the plastics and synthetic materials industry was eliminated using data constructed by the Control Data Corporation; and (2) the shares of consolidated company profits and capital stocks belonging just to the plastics and synthetic materials industry were estimated using business segment data from Compustat for the years 1976-80; and by using the average annual change over the 1976-80 period to extrapolate the plastics and synthetic materials shares of company-wide profits and capital stock backwards to 1958.

FIGURE 15

Ratio Of Earnings Before Interest And Taxes To Book Value Of Capital Stock, 1958-80



SOURCE: Office of Business Analysis, U.S. Department of Commerce and Standard & Poor's Compustat Services, Inc.

exceeded the plastics industry's rate in 1965, and it has remained higher ever since. 2/ Figure 15 also demonstrates the widening gap between the all-manufacturing rate of return and that of the plastics industry. For example, in 1965, the difference was less than 2 percentage points; but, by 1980, it had increased to more than 7 percentage points.

...The Net Rate Of Return On Common Equity In The Plastic's Industry Has Generally Exceeded The All-Manufacturing Rate.

Figure 16 compares the net rate of return on common equity in the plastics industry with that of all-manufacturing. We see there that between 1958 and 1966, the plastics industry's rate of return on common equity was superior to the all-manufacturing rate (the shaded area in Figure 16 represents the differential between the plastics industry's rate of return and the all-manufacturing rate). After 1966, however, this superiority dissipated rapidly, as a combination of business recessions, extraordinarily high capital formation rates, strong competition, high environmental expenses, and

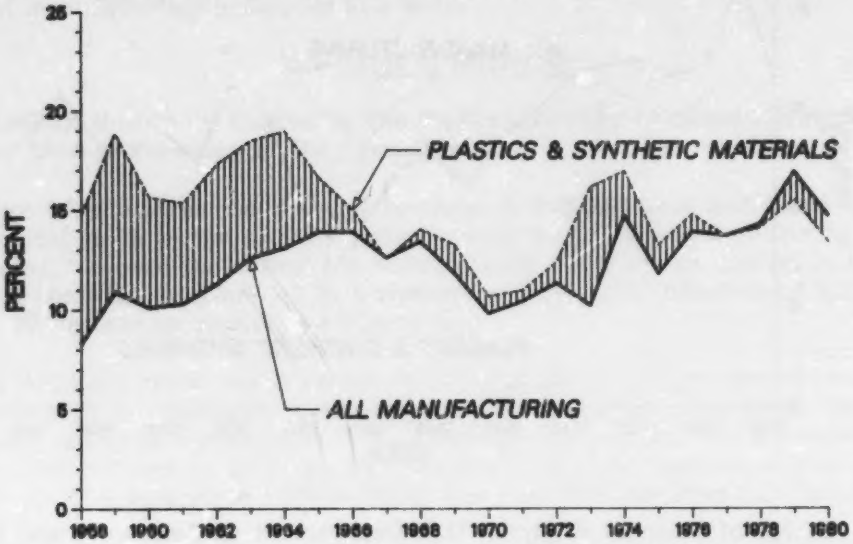
---

2/ As discussed in PART III: section B.4 below, this development can be traced to four factors: (1) the industry's extraordinary rate of capital formation between 1958 and 1969; (2) the rapid growth of government mandated pollution abatement expenditures between 1967 and 1974; (3) the impact of energy price stocks after 1973; and (4) the very competitive market in which the industry operates limited its ability to pass on cost increases.

energy price shocks acted to push the return in plastics down (see discussion in PART III: Section B.4). This is depicted in Table 7 which shows the average annual rates of return on common equity during selected peak-to-peak business cycles for plastics and all-manufacturing.

FIGURE 16

Ratio Of Net Profit To Common Stock Equity, 1958-80



SOURCE: Office of Business Analysis, U.S. Department of Commerce and Standard & Poor's Compustat Services, Inc.

TABLE 7

Average Annual After-Tax Rates Of Return On Common Equity During Selected Peak-To-Peak Business Cycles

	Business Cycle		
	1959-66	1966-74	1974-79
Plastics & Synthetic Materials...........	14.2%	12.4%	14.5%
All-Manufacturing	12.0	12.0	14.3

SOURCE: Office of Business Analysis, Department of Commerce and Standard & Poor's Compustat Services, Inc.

On average, the plastics industry's net rate of return on common equity exceeded that of all-manufacturing by 2.2 percentage points during the 1959-66 business cycle. During the 1966-74 cycle, however, the gap was narrowed to only 0.4 of a percentage point, and it was reduced further to 0.2 of a percentage point by the 1974-79 cycle.

As will be shown shortly, the plastics industry's ability to generally provide higher rates of return to common equity than those of all-manufacturing fostered a "bullish" attitude towards the industry by the market. This has been manifested in reduced risk premiums on the industry's common equity. However, this cost advantage dissipated over time, as the average annual return on equity in the plastics industry converged to the all-manufacturing rate. For example, while the plastics industry generated average annual rates of return on common equity which were 2.2, 0.4, and 0.2 percentage points higher than those of all-manufacturing during the respective business cycles, the industry's average annual costs of common equity capital were 2.3, 2.1 and 1.2 percentage points lower than the corresponding values for manufacturing industries overall (see Table 8).

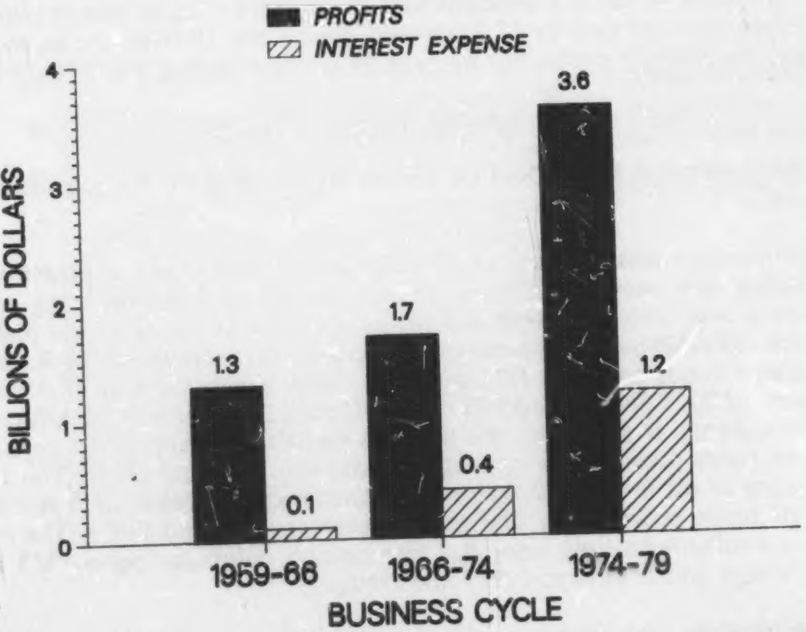
Interest Expense And Profits Increased, But...

Average annual current dollar profits and interest expense values are depicted in Figure 17 for selected peak-to-peak business cycles. Average annual profits in the plastics industry increased over 0.4 billion dollars between the 1959-66 and 1966-74 business cycles--approximately 31 percent. Between these same cycles, the average annual interest expense increased by only 0.1 billion dollars.

During the 1974-79 cycle, average annual profits rose by 1.9 billion to 3.6 billion dollars -- a 112 percent increase over 1966-74. Average annual interest expense, however, tripled -- increasing from 0.4 billion dollars during the 1966-74 cycle to 1.2 billion dollars during the 1974-79 cycle.

FIGURE 17

Average Annual Profits And Interest Expense Over Selected Peak-To-Peak Business Cycles (Billions of Dollars)



SOURCE: Office of Business Analysis, U.S. Department of Commerce and Standard & Poor's Compustat Services, Inc.

...As The Replacement Price Of Assets Increased, The Gap Between The Nominal And Real Rates Of Return On Capital Also Increased.

TABLE 8

Comparison Of Average Annual Nominal And Real Rates Of Return
On Capital Before Interest And Taxes
During Selected Peak-To-Peak Business Cycles

	Business Cycle		
	1959-66	1966-74	1974-79
Nominal Rate of Return	16.9%	12.3%	14.0%
Real Rate of Return	14.0	9.8	9.2

SOURCE: Office of Business Analysis, U.S. Department of Commerce and Standard & Poor's Compustat Services, Inc.

Table 8 contains average annual nominal and real rates of return on capital for selected post-1958 business cycles. Both the average annual real and nominal rates of return on capital fell by approximately the same amount between the 1959-66 and 1966-74 business cycles--4.2 and 4.6 percentage points respectively. However, the average annual real rate of return fell by 0.6 percentage points between the 1966-74 and 1974-79 cycles, but the average annual nominal rate of return increased by 1.7 percentage points. The difference between the industry's average annual real and nominal rates of return illustrates the impact of inflation on the price of replacing existing stocks of plant and equipment. The data in Table 8 indicate that the capital - replacement purchasing power of profits earned was reduced by 17.2 percent during the 1959-66 cycle, by more than 20 percent during the 1966-74 cycle, but by over 34 percent during the 1974-79 cycle.

B.2 Sources and Uses of Funds

Energy Shocks Created A Good Deal Of Instability Leading To An Increased Reliance On Debt Financing...

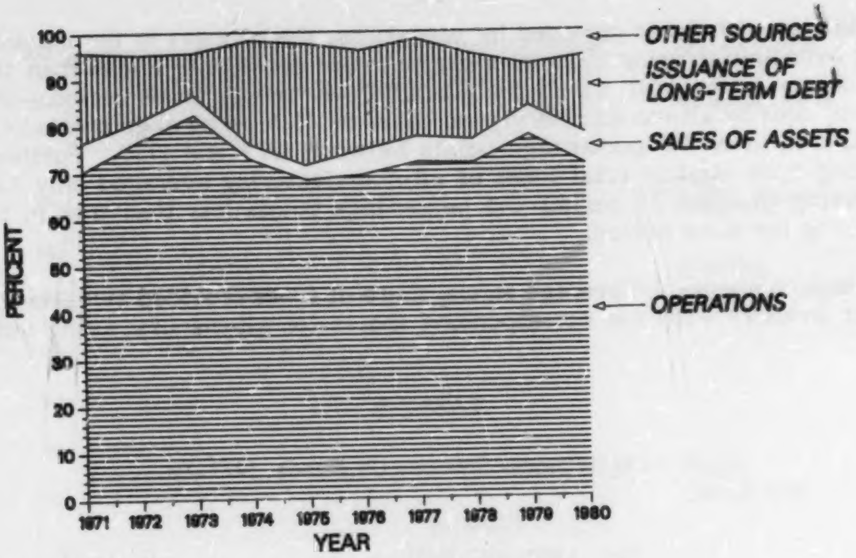
The percentage distributions of the sources of funds for the plastics industry and all-manufacturing are shown in Figure 18 for the 1971-80 period. We see there that operations was a relatively efficient and reliable source of funds to the plastics industry throughout the 1971-80 period—operations supplied an average of 73.2 percent of the plastics industry's funds between 1971 and 1980, with a minimum of 68.3 percent in 1975 and a maximum of 82.3 percent in 1973. The effect of the 1973-74 oil embargo and price shocks on the industry is shown by the massive decrease of almost 15 percentage points in the share of funds provided by operations between 1973 and 1975. The impact of the jump in the price of oil in 1979-80 was a more moderate decrease of 6 percentage points in the share of funds provided by operations between 1979 and 1980. The corresponding decreases in all-manufacturing were 9.2 percentage points between 1973 and 1975 and only 2.3 percentage points between 1979 and 1980.

On the average, the issuance of long-term debt accounted for 17.7 percent of the industry's funds during the 1971-80 period. Larger amounts of debt capital were required, however, to counter the effects of the energy price shocks after 1973 — long-term debt

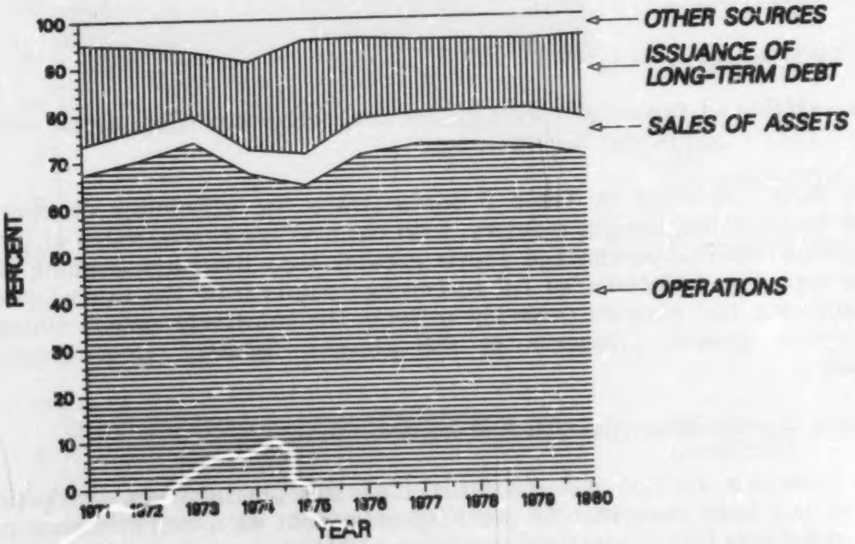
FIGURE 18

Percent Distribution Of Sources Of Funds, 1971-80

Plastics & Synthetic Materials



All-Manufacturing



SOURCE: Office of Business Analysis, U.S. Department of Commerce and Standard & Poor's Compustat Services, Inc.

averaged 21.8 percent of the industry's funds between 1974 and 1978 (see Figure 18). The most marked change in the share of funds which the industry acquired by the issuance of long-term debt took place between 1973 and 1975, with an increase of 17.1 percentage points from 9.0 percent in 1973 to 26.1 percent in 1975. A large 7.7 percentage points increase in the long-term debt share also occurred between 1979 and 1980, when the second energy shock occurred.

Again, as with funds provided by operations, the changes in the issuance of long-term debt by manufacturing industries overall were considerably less than those in the plastics industry during both the 1973-75 and 1979-80 energy crisis periods--the issuance of long-term debt by all-manufacturing increased by 10.6 percentage points between 1973 and 1975 and by only 2.9 percentage points between 1979 and 1980. Furthermore, the share of long-term debt in total funds of all-manufacturing averaged only 18.3 percent annually during the 1974-78 period--3.5 percentage points less than that in the plastics industry during the same period.

Table 9 compares the average annual share of funds provided by various sources to the plastics industry with the corresponding shares for all-manufacturing between 1971 and 1980.

TABLE 9

Average Annual Sources Of Funds, 1971-80

Source	Plastics and Synthetic Materials Industry	All-Manufacturing
Operations	73.2%	70.0%
Sale of Assets	5.0	6.8
Long-Term Debt	17.7	17.8
Other	4.1	5.4
All Sources	100.0	100.0

SOURCE: Office of Business Analysis, U.S. Department of Commerce and Standard & Poor's Compustat Services, Inc.

The data contained in Table 9 demonstrate the efficiency of operations as a supplier of funds to the plastics industry, with the average annual share of funds provided by operations being 3.2 percentage points greater than the corresponding figure in all-manufacturing. The difference of 1.8 percentage points from the sale of assets between all-manufacturing and plastics probably reflects the relatively recent vintage of assets and the better growth prospects in the plastics industry vis-a-vis those in all-manufacturing.

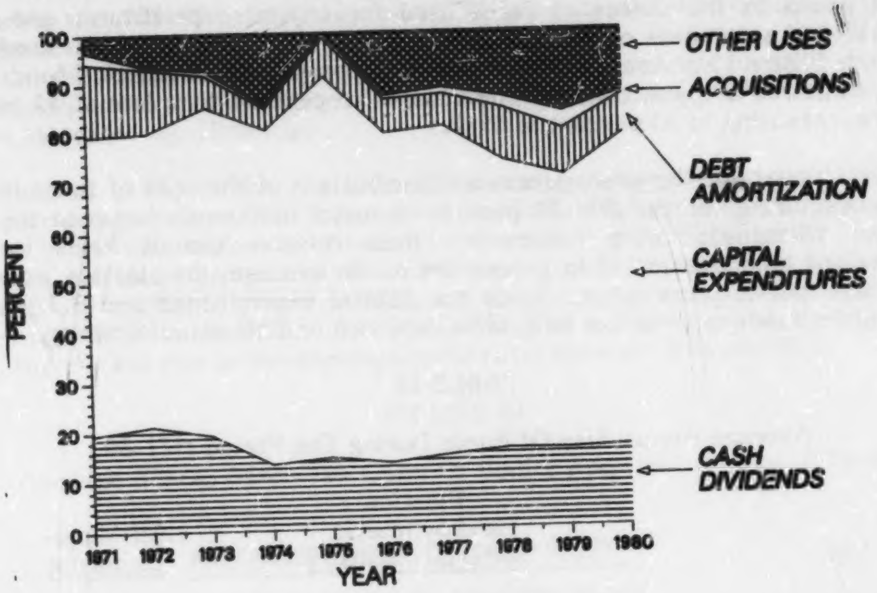
...To Finance Capital Modernization And Replacement.

The previous section demonstrates that the plastics and synthetic materials industry has not been reluctant to use long-term debt as a major source of its funds. However, with funds from operations providing a reliable base, it has been able to employ the relatively inexpensive funding provided by long-term debt to further its capital expansion and modernization requirements. Figure 19 shows the uses made of funds by the plastics industry and all-manufacturing.

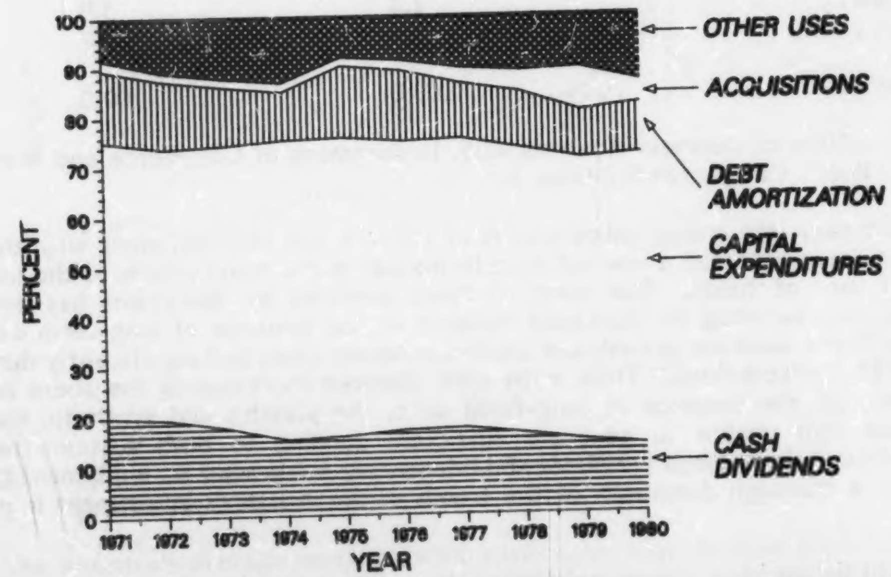
FIGURE 19

Percent Distribution Of Uses Of Funds, 1971-80

Plastics and Synthetic Materials



All-Manufacturing



SOURCE: Office of Business Analysis, U.S. Department of Commerce and Standard & Poor's Compustat Services, Inc.

As shown in Figure 19, a major change in the composition of the industry's use of funds took place between 1972 and 1975. During this period, the share of funds used for capital expenditures increased by 18.6 percentage points from 58.9 percent in 1972 to 77.5 percent in 1975; the share used to amortize debt decreased by 5.1 percentage points from 12.9 percent in 1972 to 7.8 percent in 1975; and the share used for cash dividends decreased by 6.8 percentage points from 21.2 percent in 1972 to 14.4 percent in 1975. The corresponding changes in all-manufacturing were an increase of 5.7 and 0.7 percentage points in the shares of funds used for capital expenditures and for debt amortization, and a decrease of 3.7 percentage points in the share of funds used for cash dividends (see Figure 19). After 1975, however, the proportion of plastics' funds going to capital expenditures dropped continuously from 77.5 percent to a low of 55 percent in 1979, before increasing to 63 percent in 1980.

Table 10 contains the average annual distributions of the uses of funds in plastics and all-manufacturing for the 1971-80 period. A major difference between the plastics industry and all-manufacturing occurs in their relative use of funds for capital expenditures and amortization of long-term debt. On average, the plastics industry used 6.4 percentage points more of its funds for capital expenditures and 3.3 percentage points less of its funds to amortize long-term debt than did all-manufacturing.

TABLE 10

Average Annual Use Of Funds During The Period 1971-80

Use	Plastics and Synthetic Materials Industry	All-Manufacturing
Cash Dividends	16.3%	16.6%
Capital Expenditures	63.8	57.4
Amortize Long-Term Debt	8.7	12.0
Acquisitions	1.4	5.3
Other	9.8	8.7
Total Uses	100.0	100.0

SOURCE: Office of Business Analysis, U.S. Department of Commerce and Standard & Poor's Compustat Services, Inc.

In summary, the energy price shocks of 1973-74 and 1979-80, along with the 1974-75 recession, have effected a marked transformation in the distributions of the industry's sources and uses of funds. The share of funds provided by operations has decreased appreciably, necessitating an increased reliance on the issuance of long-term debt; and the share of funds used for growth and capital modernization fell significantly during the latter half of the seventies. Thus, even with sizeable increases in the share of funds obtained through the issuance of long-term debt, the plastics and synthetic materials industry was still unable to generate sufficient funding to both sustain the plant expansion of its halcyon days (1959-66) and adequately modernize its equipment (Section A.1 contains a thorough discussion of the trends in the industry's investment in physical capital).

As will be shown in the succeeding section, the two energy price shocks have also had a telling effect on the risk premiums placed on the industry's debt and equity issues — the weighted cost of capital, which is a weighted sum of the costs of all internal and external funding, almost tripled between 1972 and 1979.

B.3 Costs of Capital

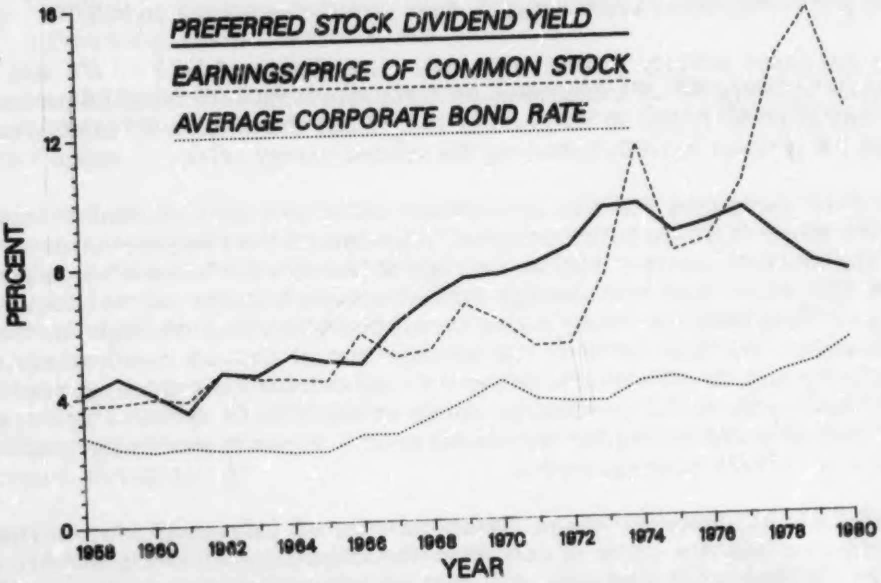
Costs of Capital To Plastics Industry Increased, But Generally Remained Lower Than Those in All-Manufacturing, And...

During the 1958-80 period, the costs of both equity and debt capital to the plastics and synthetic materials industry rose (see Figure 20). The most sizeable increase occurred in the cost of common equity--the ratio of earnings to price per share of common stock; however, the coupon rates on the industry's preferred stock and corporate bonds also increased significantly.

As shown in Figure 20, the industry's average earnings/price ratio increased by only 1.6 percentage points from 3.8 percent in 1958 to 5.4 percent in 1972. Reflecting the decline in the industry's rate of return between 1964 and 1970 (Figures 15 and 16), its market price per share of common stock fell approximately 29 percent from an average price of $104.30 in 1958 to $70.40 in 1972, and the industry's earnings/share decreased by 3.3 percent from $3.93 in 1958 to $3.80 in 1972. The combination of these two factors produced the modest rise in the earnings/price ratio between 1958 and 1972.

FIGURE 20

Average Annual After-Tax Costs Of Equity And Debt Capital, 1958-80



SOURCE: Office of Business Analysis, U.S. Department of Commerce and Standard & Poor's Compustat Services, Inc.

The industry's average earnings/price ratio more than doubled from 5.4 percent in 1972 to 11.5 percent in 1974 (see Figure 20). The oil embargo had created uncertainty in the market about the industry's future which was reflected by the price per share of common stock dropping from $70.40 in 1972 to $49.75 in 1974--over 29 percent.

Ironically, this decline in the price per share of common was accompanied by an increase of over 50 percent in the industry average earnings/share -- from $3.80 in 1972 to $5.74 in 1974. The combination of these two factors produced the massive increase in the industry's cost of common equity.

In 1975, the market displayed renewed confidence in the industry's common stock and the price/share rose by almost $8.00 to $57.70. This confidence however, was short-lived, and the industry's average price per share of common fell by over 40 percent to its post-1958 low of $34.10 in 1979. This massive decline in the average price/share -- of common stock combined with an earnings decrease of $.50/share to produce an increase of 4.2 percentage points in the earnings/price ratio--from 11.5 percent in 1975 to its post-1958 high of 15.7 percent in 1979.

Throughout the pre-1966 period, the industry's average cost of preferred equity -- the dividend yield--remained less than 5.2 percent, with an average annual value of 4.6 percent (see Figure 20). In 1967, the dividend yield began a steady increase until it peaked at 9.7 percent in 1974--4.8 percentage points higher than its 1966 value of 4.9 percent. During the post-1974 period, the industry's average dividend yield fell to 8.8 percent in 1975; rose to 9.5 percent in 1977; and then decreased to 7.5 percent in 1980.

Meanwhile, the industry's after-tax cost of debt capital (the corporate bond rate) remained almost static between 1958 and 1965--fluctuating a few tenths of a percentage point around 2.3 percent. During the next five years, however, the industry's average corporate bond rate doubled--increasing from 2.2 percent in 1965 to 4.3 percent in 1970. In 1971, the industry average corporate bond rate then fell by 0.6 percentage points to 3.7 percent and remained at approximately that level in both 1972 and 1973.

The increased anxiety generated by the oil embargo of 1973 - 1974 was reflected in the plastics industry by an increase in its corporate bond rate from 3.6 percent in 1973 to 4.3 percent in 1975. It fell to 3.9 percent in 1977 but then increased rapidly to its post-1958 high of 5.4 percent in 1980, following the second energy crisis.

Table 11 compares the average annual costs of equity capital to the plastics industry with those of all-manufacturing and it compares the average annual cost of debt capital to the plastics industry with an average of Moody's AAA and BAA corporate bond rates. We see there that the average annual costs of equity capital to the plastics industry have remained less than those to all-manufacturing throughout the 1958-80 period. However, the gap between the average annual cost of common equity to the plastics industry and to all-manufacturing decreased from 2.1 percentage points in the 1966-74 business cycle to 1.2 percentage points in the 1974-79 cycle. The corresponding gap in the cost of preferred equity decreased by only 0.1 of a percentage point between the 1966-74 and 1974-79 business cycles.

Meanwhile, the average annual after-tax cost of long-term debt to the plastics industry increased slightly more rapidly than the composite of Moody's AAA and BAA bond rates. The average annual after-tax cost of debt capital for plastics was the same as the composite of Moody's AAA and BAA bond rates during both the 1959-66 and the 1966-74 business cycles. During the 1974-79 business cycle, the average annual cost of debt capital to plastics increased to 4.3 percent -- 0.1 percentage points lower than the Moody's average of 4.4 percent.

TABLE 11

Average Annual After-Tax Costs of Capital During Selected Peak-to-Peak Business Cycles

	Business Cycle		
	1959-66	1966-74	1974-79
Earnings/Price			
Plastics & Synthetic Materials..........	4.4%	6.5%	11.4%
All Manufacturing	6.7	8.6	12.6
Preferred Dividend Yield			
Plastics & Synthetic Materials..........	4.5	7.6	8.7
All Manufacturing	6.0	11.1	12.1
Corporate Bond Rates			
Plastics & Synthetic Materials..........	2.4	3.5	4.3
Average of Moody's AAA & BAA	2.4	3.5	4.4

SOURCE: Office of Business Analysis, U.S. Department of Commerce and Standard & Poor's Compustat Services, Inc.

...The Industry's Rate Of Return To Capital Exceeded Its Weighted Cost Of Capital, Throughout The 1958-76 Period; But, Since 1977, Capital Costs Have Been Higher Than Return To Capital.

Since the plastics and synthetic materials industry employs a mixture of debt and equity instruments together with internal funds as sources of capital, the relative costs shown in the previous section do not tell the complete story. The actual or composite costs of capital to the industry are a weighted sum of the costs of common equity funds (both internal and external), preferred equity funds, and long-term debt funds, which contributed to the industry's sources of funds. Following established practice, the implicit cost of using internal funding is assumed to be the same as that of common equity funding, i.e. the earnings/price ratio. Figure 21 shows the plastics industry's weighted after-tax cost of capital vis-a-vis its nominal after tax plus interest expense rate of return to capital. 3/

As shown in Figure 21, the plastics industry's nominal rate of return to capital has exceeded its weighted cost of capital throughout the 1958-76 period (the shaded area in Figure 21 represents the difference between the industry's rate of return to capital and

---

3/ The comparisons, between the cost of capital and the rate of return on capital in this section, can only be considered an approximation, because the comparison is between the marginal cost of acquiring new capital assets and the average rate of return derived from all capital assets. An exact statement requires comparing the cost required to finance each unit of capital with the rate of return derived from it.

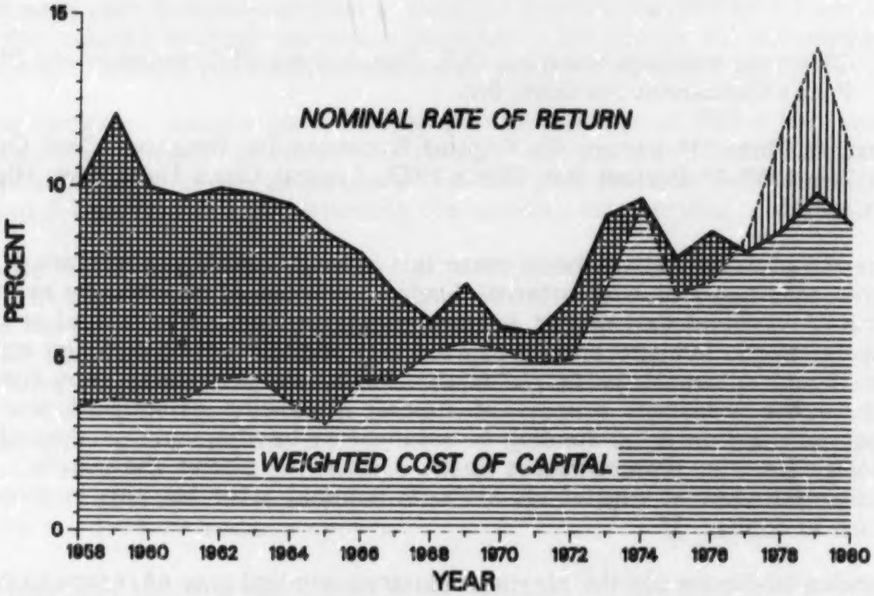
the weighted cost of capital). This difference represents those funds which can be employed by the industry for cash dividends, debt amortization, capital modernization, etc.

Throughout the 1958-66 period, the industry's rate of return on capital exceeded its weighted cost of capital by a sizeable margin (see Figure 21). However, the industry's rate of return on capital and its weighted cost of capital were beginning to converge. For example, in 1959, the industry's after-tax rate of return on capital exceeded its after-tax weighted cost of capital by 8.4 percentage points but, in 1966, the difference had narrowed to 3.8 percentage points.

Figure 21 shows that this pattern of falling returns on capital and increasing costs of capital persisted through 1970, with the industry's after-tax rate of return on capital falling to 6 percent while its after-tax weighted cost of capital rose to 5.2 percent -- the gap had been further reduced to only 0.8 of a percentage point. Between 1970 and 1974, the industry's rate of return on capital increased by 4 percentage points to 10 percent in 1974, but its weighted cost of capital increased by 4.2 percentage points to 9.4 percent.

FIGURE 21

Weighted Cost Of Capital After Taxes Vs. Nominal Rate Of Return To Capital After Taxes Plus Interest Expense



SOURCE: Office of Business Analysis, U.S. Department of Commerce and Standard & Poor's Compustat Services, Inc.

The movement of the two parameters was approximately the same from 1974 to 1976. However, in 1977, while the industry's weighted cost of capital increased by 1.3 percentage points to 8.5 percent, its rate of return on capital decreased by 1 percentage point to 8.1 percent — the industry's cost of capital had exceeded it rate of return on capital for the first time. As shown in Figure 21, the difference between the after-tax weighted cost of capital and the after-tax rate of return on capital increased to 3 percentage points in 1978 and to 3.6 percentage points in 1979, before it decreased to 2.3 percentage points in 1980.

Table 12 compares the industry's average annual weighted cost of capital with its average annual nominal rate of return to capital for selected peak-to-peak business cycles. Between 1959 and 1966, the industry's after-tax average annual nominal rate of return to capital of 9.8 percent exceeded its after-tax average annual weighted cost of capital of 3.9 percent by 5.9 percentage points (see Table 12). During this period, the plastics industry was able to use inexpensive internal and external funds as a fuel for expansion of its capital stock, since the returns that were being generated to capital were more than sufficient to cover the costs of debt amortization and interest repayment and still provide hefty dividends and price appreciation to its stockholders.

During the 1966-74 period, the industry's average annual weighted cost of capital increased by 2.8 percentage points to 5.7 percent, but its average annual nominal rate of return to capital had decreased by 2.3 percentage points to 7.5 percent. The difference between returns to capital and costs of capital had narrowed to 1.8 percentage points.

TABLE 12

Comparison Of Average Annual After-Tax Nominal Rates Of Return To And Cost Of Capital Rates During Selected Peak-to-Peak Business Cycles

	Business Cycle		
	1959-66	1966-74	1974-79
Rate of Return on Capital a/	9.8%	7.5%	9.1%
Weighted Cost of Capital	3.9	5.7	9.6

a/Includes Interest Expense.
SOURCE: Office of Business Analysis, U.S. Department of Commerce and Standard & Poor's Compustat Services, Inc.

During the 1974-79, period, the industry's average annual weighted cost of capital increased 3.9 percentage points to 9.6 percent, but its average annual nominal rate of return to capital increased by only 1.6 percentage points to 9.1 percent. On average, the industry's cost of capital exceeded its average annual nominal rate of return to capital by 0.5 of a percentage point during the 1974-79 cycle.

Summary

Since 1973, the plastics and synthetic materials industry has experienced a marked deterioration in its financial position from its halcyon days of the early to mid-sixties. Its rate of return on common equity, which exceeded the all-manufacturing rate in all but four years between 1958 and 1978, converged continously to the all-manufacturing rate during 1973-78 and in 1979-80 fell below the all-manufacturing rate. The average share of funds derived from operations decreased by nearly 10 percentage points from the values recorded in 1973. Meanwhile, the portion of its funds used to finance new capital expenditures declined continously from 77.5 percent in 1975 to 55 percent in 1980, while a larger portion went to finance less risky acquisitions of and investment in already established business enterprises. The difference between the industry's after-tax

average annual nominal rate of return to capital and its after-tax average annual weighted cost of capital went from plus 5.9 percentage points in the 1959-66 cycle to minus 0.5 of a percentage point in the 1974-79 cycle. This post-1973 deterioration reflects the effects of several factors: the energy price shocks of 1973-74 and 1979-80, the 1974-75 recession, strong domestic and foreign competition, and high environmental expenses, etc. As a result of these factors, the average costs of common equity to the industry in 1974-79 were not only more than 75 percent higher than they were in 1966-74 but also they were, for the first time, higher than its costs of preferred equity and debt.

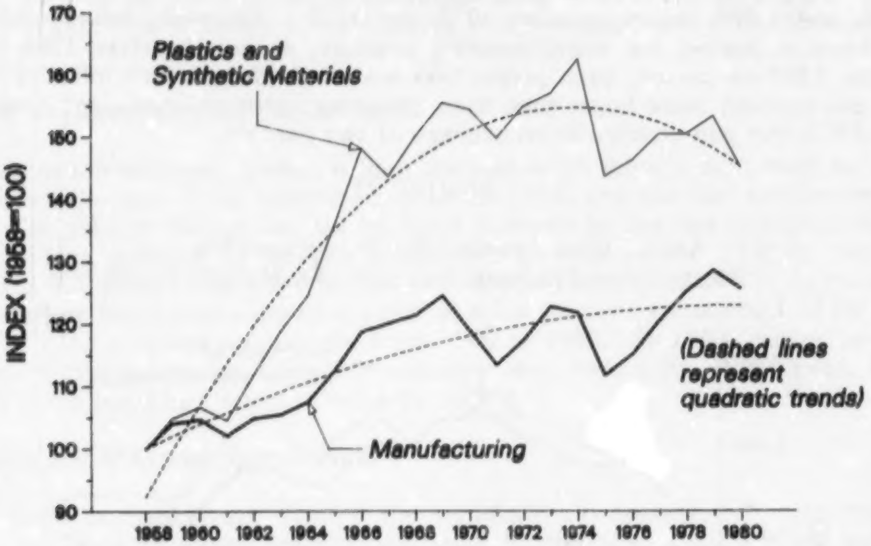
C. LABOR INPUTS

C.1 Employment and Hours

The plastics and synthetic materials industry employed 151,600 people in 1980, and in terms of employment size ranked 46th out of 143 U.S. manufacturing industries. 1/ Since 1958 the long-term employment growth trend in this industry has been markedly different than in manufacturing as a whole; as Figure 22 shows, the plastics industry's employment growth followed a pronounced parabolic trend, unlike the nearly linear growth trend associated with manufacturing.

FIGURE 22

Total Employment: Plastics And Synthetic Materials
Vs. All-manufacturing
(Index, 1958=100)



SOURCE: Bureau of the Census and Office of Business Analysis, U.S. Department of Commerce.

Employment Growth Dropped Sharply After 1966 . . .

Employment in this industry expanded at a rate of almost five percent annually from 1958 to 1966, and the workforce grew by 50 thousand workers, reaching 154,800 in 1966. After 1966, the long term trend in employment was essentially flat; employment rose to a peak of 169,000 in 1974, then declined below the 1966 level, to just 151,600 by 1980.

1/ The 1972 Standard Industrial Classification code lists 143 3-digit manufacturing industries.

. . . And The Employment Drop Affected Production And Nonproduction Workers Equally

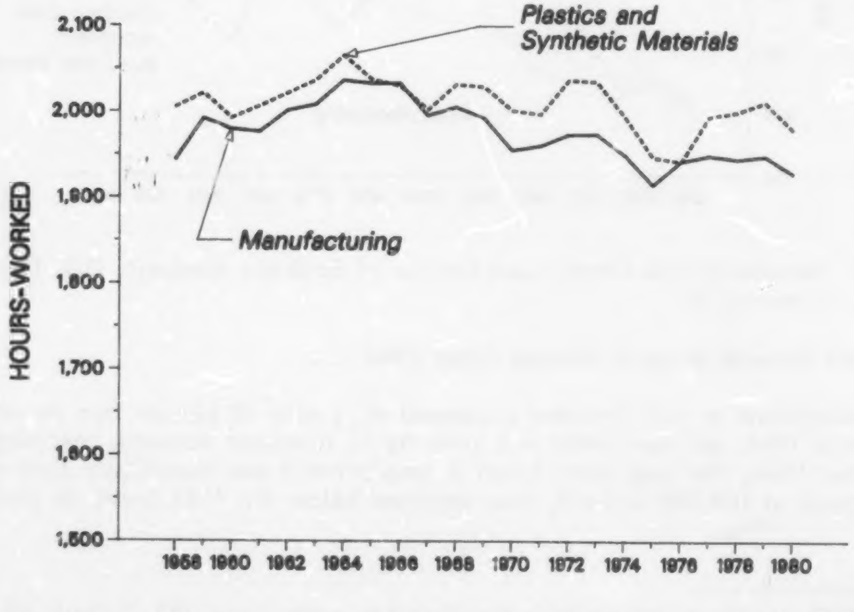
The drop-off in employment after 1966 affected production and nonproduction workers equally. Their respective shares in total employment varied little between 1958 and 1980 — production workers averaged 71 percent of total employment, and nonproduction workers averaged 29 percent. The ratio of nonproduction workers to production workers — a crude indicator of the level of technical advancement in the production process — remained quite stable over the 1958-80 period; this ratio was nearly constant over the interval, averaging 0.40 nonproduction workers for each production worker. It is important to note, however, that the level of this ratio has historically been quite a bit above the level for all-manufacturing: 0.41 vs. 0.32 in 1959-60, 0.40 vs 0.34 in 1966-74, and 0.42 vs. 0.36 in 1974-79; the nonproduction/production worker mix in all-manufacturing moved over time toward the levels found in the plastics industry.

Hours-worked By Production Workers Dropped, But Remained Above The All-manufacturing Average

Annual hours-worked by production workers in plastics and synthetic materials declined slightly over time, averaging 2,027 in the 1959-66 period, 2,016 between 1967 and 1974, and 1,979 hours between 1975 and 1979. However, hours-worked in this industry have exceeded the manufacturing average, especially after 1966 (see Figure 23). In the 1959-66 period, each production worker in the plastics industry worked, on average, one percent more hours than their counterparts in all-manufacturing. Between 1966 and 1980, this gap doubled to an average of two percent.

FIGURE 23

Annual Hours-worked Per Production Worker:
Plastics And Synthetic Materials Vs. Manufacturing



SOURCE: Bureau of the Census and Office of Business Analysis, U.S. Department of Commerce.

Paid Time Off Rose Between 1958 And 1966, Then Leveled Off

Hours-paid per production worker fell less than hours-worked, due to increases in paid time off over the 1958-80 period. The number of hours paid but not worked (per production worker) rose from roughly six percent of all hours paid in 1958 to eight percent in 1966; paid time off remained at this level up to 1980. In contrast, paid time off was five percent of all hours paid to production workers in all-manufacturing in 1958, and rose linearly to 7 percent in 1980.

Behind The 1966-80 Employment Drop: A Build-Up Of Plant And Equipment Stock . . .

The drop-off in steady employment growth after 1966 followed a period of strong investment growth in the industry: net "productive" capital stock 2/ increased 62 percent between 1959 and 1966, and half of that increment came in the years 1964-66 alone. Between one-quarter and one-third of this investment spurt went into new plants and production facilities, and the remainder went to new equipment purchases. This trend continued until 1968; but after that year, plant investment dropped to between five and ten percent of all new investment in the plastics and synthetic materials industry. The 1959-68 buildup in plant investment, followed by a increase in equipment stock, suggests a move in this industry toward highly-automated plants with state-of-the-art equipment.

. . . Resulting In Higher Capital Per Worker. . .

As this new investment came on line, the industry's labor input needs declined. 3/ Figure 24 shows the growth in investment prior to 1966, and the flat employment trend thereafter. The substitution of capital for labor is shown by the rise in capital per worker; this ratio was growing at a 1.5 percent annual rate in the 1958-66 period, but increased to a 4.2 percent average annual rate thereafter, up to 1980. In comparison, capital per worker in all-manufacturing grew at a 0.6 percent annual rate in the 1958-66 period, and at a 2.9 percent annual rate from 1966 to 1980. By 1980, capital per worker in the plastics and synthetic materials industry was twice its 1958 level, while in manufacturing the level had increased only by half. 4/

. . . And Rising Labor Productivity Levels

The surge in investment enabled the workforce to become far more productive after 1966. As Table 13 shows, labor productivity increased at a 6.6 percent annual rate in the 1966-74 period, versus a 3.6 percent rate in the 1959-66 period. Productivity growth continued at a 6.1 percent average annual rate after 1974. 5/

2/ "Productive" capital stock excludes investment in pollution abatement equipment. See Section A of Part II for a complete discussion of capital stock issues in this industry.

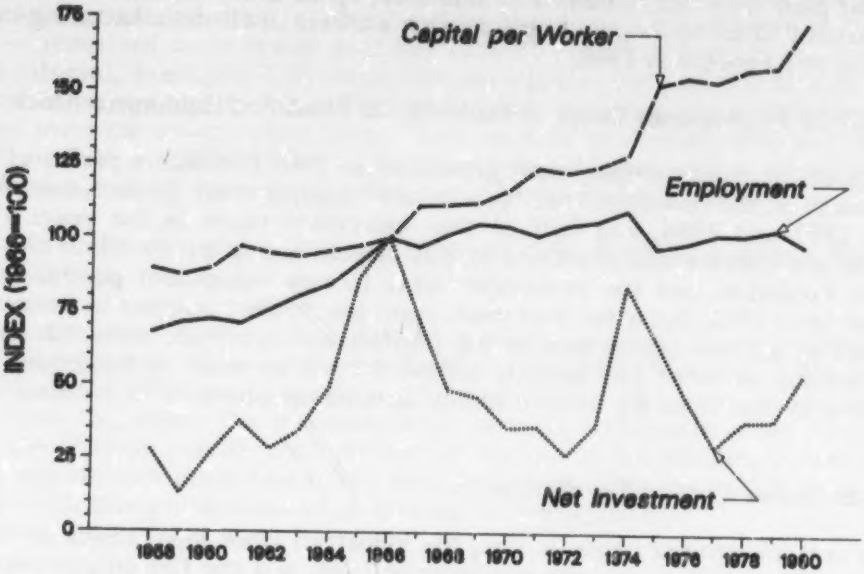
3/ Industry sources and government data indicate that the slowdown in employment growth was accomplished through attrition and re-assignment; at the plant level, some re-training programs were instituted as well.

4/ See Section A.4 for a more complete discussion of capital per worker.

5/ A detailed analysis of the industry's productivity performance over the 1958-80 period is found in PART III of this Report.

FIGURE 24

Employment, Investment, And Capital Per Worker
(Index, 1966=100)



SOURCE: Bureau of the Census and Office of Business Analysis, U.S. Department of Commerce.

TABLE 13

Factors Affecting Productivity Growth
(Average Annual Percent Change)

Interval	Real Output	Employment	Capital Stock	Capital/ Worker	Productivity
1959-66	9.0%	5.1%	7.2%	2.1%	3.6%
1966-74	7.9	1.2	4.4	3.3	6.6
1974-79	5.3	-1.0	3.1	4.5	6.1

SOURCE: Office of Business Analysis, U.S. Department of Commerce

C.2 Labor Quality: Demographic Characteristics of the Workforce

The technological and productivity growth potential of any industry is closely related to the "quality" of the industry's workforce — that is, the background of experience and technical expertise which the workers bring to their jobs. 6/ Examined below

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6/ Much remains unknown about the interaction between cost-saving technical innovations and productivity, but there is a consensus that the quality of the labor force are two measures that indicate the general experience levels of the workforce -- the proportion of females in the production workforce, and the age distribution of workers 7/ -- and two indicators of the level of technical expertise of the workforce -- educational attainment, and the occupational distribution of the workforce. 8/.

Females In The Workforce: Increased Shares Since 1958 . . .

By 1980, female workers accounted for nearly one out of every three employees in the plastics and synthetic materials industry, an increase from their 1958 share of one in five employees. Their distribution among occupations was not uniform: in general, females in this industry comprised a larger proportion of nonproduction than production jobs. Table 14 shows female workers' share of total employment and production/nonproduction worker employment over selected intervals since 1958.

TABLE 14

Female Share Of Employment
(Interval Averages)

Interval	Total Employment	Production Workers	Nonproduction Workers
1959-66	18.8%	15.5%	25.5%
1967-74	22.8	21.3	26.3
1975-80	22.9	20.5	28.0

SOURCE: Bureau of the Census and Office of Business Analysis, U.S. Department of Commerce

. . . Tempered By The Shock Of The 1974-75 Recession

The data underlying Table 14 show that females increased their share of plastics' employment significantly in the early 1970's, even though this was generally a period of stagnant employment growth in overall manufacturing. The major recession of 1974-75, however, slowed their job growth in this industry, and return their share to the levels of

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is a major factor not only in an industry's awareness of new technical ideas but also in its ability to absorb and successfully apply these ideas, and to effectively utilize improvements embodied in new capital.

7/ The use of the age and sex distribution of the workforce as a barometer of the experience level embedded in the workforce is a standard feature in economic studies of productivity growth and technical progress. (See also Footnote 10, below)

8/ In summarizing the current research on the dynamics of the innovation process, Utterback concludes: ". . . personal contacts, education, and experience constitute the largest portion of information sources used in originating ideas for innovation. The data from these studies suggest that education is the primary avenue through which basic findings are translated into engineering practice." See J.R. Utterback, "Innovation in Industry and Diffusion of Technology," Science, Vol. 183, Feb. 1974, pp. 620-626. For further background, see A.H. Rubenstein, "The Role of Imbedded Technology in Industrial Innovation," in Special Study on Economic Changes, Vol. 3, Research and Innovation: Developing a Dynamic Nation, Joint Economic Committee, Dec. 1980.

the late 1960's. The recession affected females in both production and nonproduction jobs, though employment in nonproduction occupations recovered more vigorously after the recession. By contrast, the manufacturing sector as a whole experienced no decline in female employment shares during this period.

The Age Distribution Of The Workforce: The Biggest Gains In Shares of Employment Came Among The Youngest And Oldest Workers

During the 1958-80 period over half of the workforce in the plastics and synthetic materials industry was in the 25-44 year-old age group; this pattern held true for both production and nonproduction workers, as Table 15 shows. The only age groups which experienced growth were the youngest and oldest categories. Those workers aged 14-24 years -- arguably the most inexperienced segment of the workforce -- accounted for just under 10 percent of total employment in 1958, but grew in number to account for over 17 percent of the workforce by 1980; and, as Table 15 shows, these youngest workers mainly entered production worker occupations. Another group which increased its employment share was the oldest segment of workers -- those over 55 years of age. Their share of nonproduction jobs grew from 10 percent in 1958 to 16 percent in 1980. While the direct effect of these two age-related demographic changes on productivity growth cannot be determined, anecdotal evidence (see footnote 9) lends credence to the assessment that the combined impact was negative.

Over the same period, the manufacturing sector as a whole had a workforce profile very similar to that of the plastics industry -- roughly half of the workforce in manufacturing was in the 25-44 year-old age group throughout the 1958-80 period. The bulk of growth occurred among younger workers -- those aged 14-24 years -- in both plastics and synthetic materials and in overall manufacturing, as the "baby boom" generation came of age and entered the labor force. In both all-manufacturing and plastics and synthetic materials, younger workers primarily found production worker jobs.

The Plastics Industry Had An Above-average Cohort Of 25-44 Year-Old Nonproduction Workers -- Those Likely To Be At The Peak Of Their Contributions To Productivity

Perhaps the most significant trait of the plastics industry's workforce, though, is that the proportion of nonproduction workers in the 25-44 year-old age group was above that found in manufacturing industries overall during the plastics industry's most outstanding growth years, between 1958 and 1966. 9/ In 1958, more than 59 percent of plastics workers were in this group, compared to only 51 percent in all-manufacturing. In 1966 the proportions were 55 percent to 48 percent. By 1980, however, the gap had closed, with 52 percent in both plastics and all-manufacturing.

9/ Since the mid to late-sixties, there has been, among highly-educated scientists and engineers in the 25-44 year-old age group, an exodus from jobs previously held in mature and declining industries towards jobs in industries with a greater appetite for entrepreneurship and risk-taking. One of the primary reasons cited for this exodus is that mature industries are populated and dominated by an older top management not receptive to new technologies and innovation, while the new industries offer ". . . a business environment and culture that accommodates their needs and aspirations." (Thomas O'Boyle, "U.S. Basic Industries Are Hindered By Loss Of Scientific Talent", Wall Street Journal, July 27, 1984, p.1.)

TABLE 15

Percent Distribution Of Employment, By Age Group

	Plastics & Synthetic Materials			Manufacturing		
	1958	1966	1980	1958	1966	1980
Production Workers	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
14-24 Years-old	8.3	14.2	20.2	12.5	16.3	20.1
25-44 Years-old	54.1	52.6	51.8	51.0	45.2	47.7
25-34 Years-old	25.2	27.2	28.3	24.0	21.1	27.4
35-44 Years-old	28.9	25.4	23.5	27.0	24.1	20.3
45-54 Years-old	25.3	21.4	16.3	21.8	22.8	17.7
55 + Years-old	12.3	11.8	11.7	14.7	15.7	14.6
Nonproduction Workers.............	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
14-24 Years-old	12.6	14.1	11.2	17.3	18.0	14.5
25-44 Years-old	59.3	54.9	51.9	51.4	48.0	52.2
25-34 Years-old	31.9	27.2	25.6	26.1	22.8	29.1
35-44 Years-old	27.4	27.7	26.3	25.3	25.2	23.1
45-54 Years-old	17.8	20.2	20.9	18.7	20.3	18.4
55 + Years-old	10.2	10.8	16.0	12.6	13.7	14.9

SOURCE: Bureau of the Census and Office of Business Analysis, U.S. Department of Commerce

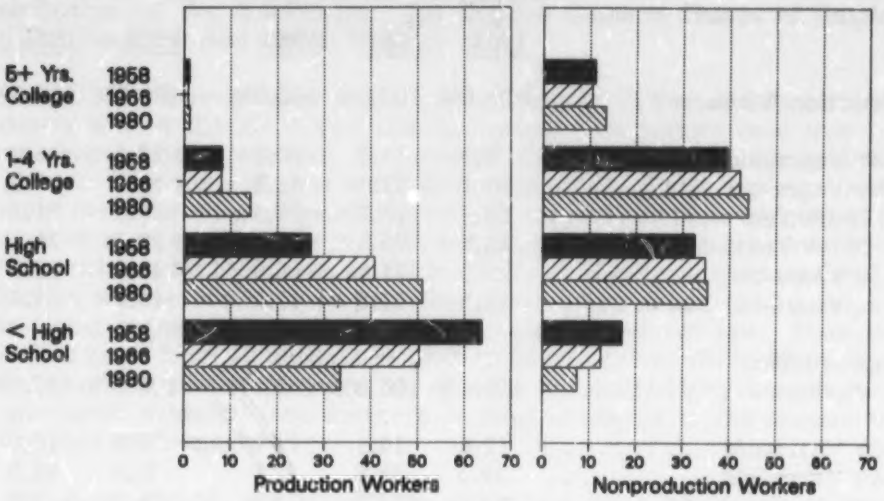
Measuring The Technical Expertise Of The Workforce: Education Levels In The Industry, As In All-manufacturing, Improved Over Time

In general, educational attainment in the plastics and synthetic materials industry followed the trends in aggregate manufacturing. In 1958, 48 percent of the workers in the plastics and synthetic materials industry had not completed a high school education. Twenty-nine percent had graduated from high school, and 22.8 percent had some college education. By 1980, the shift toward higher education had left only 25 percent of plastics and synthetic materials' workers without high school diplomas; 46 percent had completed a high school education, and the remainder had some additional education. Moreover, the number of workers with college experience had increased by nearly a third.

Trends in educational attainment differed markedly among occupational groups. Production workers with a high school education increased from 27 percent of the workforce in 1958 to 51 percent in 1980. Figure 25 illustrates this predominance of high school completion among production workers and the two-thirds increase since 1958 in the number of production workers with college experience. The bulk of the growth in the latter group was among those completing 1-3 years of college. College graduates (4 years) rose from two percent to roughly 2.5 percent of all production workers in the plastics and synthetic materials industry between 1958 and 1980, while the proportion of production workers with 1-3 years of college rose from ten percent in 1958 to 15 percent in 1980.

FIGURE 25

Educational Attainment, By Type Of Worker



SOURCE: Office of Business Analysis, U.S. Department of Commerce.

Among nonproduction workers, the most noticeable trend was the further decline in the number of workers without high school educations; the share of these workers dropped from 17 to 7 percent of all production workers.

Nonproduction Workers In Plastics Achieved Far Higher Levels Of Education Than Their Counterparts In All-manufacturing

Below the college level, the educational trends in this industry mirrored the all-manufacturing pattern over the 1958 to 1980 period. Above that level, however, this industry far exceeded the manufacturing-wide educational level. Table 16 shows that the industry not only had a history of above-average employment of nonproduction workers with higher education levels but also that the trend in this proportion was rising over time. Importantly, this increasingly well-educated workforce also complemented the increased capital sophistication of the industry that was discussed in the first part of this Chapter.

TABLE 16

Workers With Higher Education Levels

	Plastics And Synthetic Materials			Manufacturing		
	1958	1966	1980	1958	1966	1980
Proportion of Total Employment with:						
1-4 Years College						
All workers	7.6%	8.6%	9.1%	3.8%	4.5%	6.7%
Production	1.9	1.6	2.5	0.9	0.8	2.1
Nonproduction	19.1	24.5	22.9	12.7	16.2	18.5
5 + Years College						
All workers	4.4	3.8	5.2	1.8	1.8	4.0
Production	1.1	0.9	1.2	0.4	0.4	1.1
Nonproduction	11.1	10.5	13.4	6.0	6.3	11.4

SOURCE: Bureau of the Census and Office of Business Analysis, U.S. Department of Commerce

Higher Education Levels Provided The Foundation For An Occupational Distribution Quite Different From All-manufacturing

As noted before, the shares of production and nonproduction jobs held by workers in the plastics and synthetic materials industry has remained relatively stable over time. Table 17 shows that this pattern runs counter to the all-manufacturing trend toward greater proportions of nonproduction jobs.

Among production-related occupations, only craftsmen and kindred workers experienced employment growth after 1966. The bulk of the growth in total employment after 1966, however, came from increases in nonproduction worker employment: among managers and administrators, laborers, and clerical workers. Most of these nonproduction worker categories comprised higher proportions of total employment than in manufacturing overall.

An outstanding difference in the occupational skill levels found in plastics relative to all-manufacturing can be seen in the relative share of employment held by professional workers. Between 1958 and 1966, their share in plastics was almost twice that found in manufacturing overall. By 1980, while the difference had declined substantially, the professional share of employment in plastics was still more than 33 percentage points greater than the professional share in all-manufacturing.

Another important difference is found in the rankings among occupational groups between plastics and all-manufacturing. Reflecting above-average technical requirements, professional and technical workers are the third largest occupational group in the plastics and synthetic materials industry, as opposed to fourth largest in manufacturing overall; managers ranked fourth, as opposed to sixth.

TABLE 17

Percent Distribution Of Employment, By Occupation Group

	Plastics And Synthetic Materials			Manufacturing		
	1958	1966	1980	1958	1966	1980
Total Employment	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Production Workers	70.6	70.0	68.9	75.6	76.0	72.0
Craftsmen	21.9	18.7	22.6	21.0	19.6	22.7
Operatives	38.5	44.1	37.6	45.3	48.6	39.8
Service Workers	3.3	2.9	2.2	1.9	2.3	2.4
Laborers	6.9	4.3	6.4	7.4	5.4	7.1
Nonproduction Workers	29.4	30.0	31.1	24.4	24.0	28.0
Professionals	11.7	13.8	12.0	6.2	7.0	8.9
Managers	4.6	4.9	6.5	5.4	5.2	6.1
Clerical Workers	10.6	9.3	10.8	9.9	9.2	10.4
Sales Workers	2.5	1.9	1.8	2.9	2.7	2.6

SOURCE: Bureau of the Census and Office of Business Analysis, U.S. Department of Commerce

Comparing The Plastics And Synthetic Materials Industry With A Mature Industry — Primary Iron And Steel

The preceding pages have used the manufacturing industry as the benchmark against which the plastics industry's workforce is compared, and the above-average nature of its workforce has been evident. All-manufacturing is a heterogeneous aggregate, however, and comparisons with it tend to obscure meaningful inter-industry disparities. To highlight the above-average nature of the plastics industry even further, we present a comparison of the demographic characteristics of its workforce with those of a declining industry: primary iron and steel. Table 18 presents a summary and comparison of the levels of labor quality — workforce experience levels, and technical expertise levels -- in plastics, iron and steel, and all-manufacturing.

The existence of relatively high levels of experience among workers in the plastics and synthetic materials industry is indicated by the first half of Table 18. The proportion of production workers who were female — a possible indicator of inexperience 10/ -- was

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10/ The use of the proportion of females in the workforce as an index of inexperience in the labor force is unquestionably controversial. Nevertheless, most observers note that males have historically maintained a more permanent and unbroken workforce profile. Thus, men and women, who are similar with respect to other relevant demographic characteristics — age, education, and occupation -- are likely to have much different degrees of on-the-job experience. Economic studies suggest that between 4.0 and 10.0 percent of the decline in the rate on U.S. productivity growth since the mid-sixties was the result of the increased proportions of females and younger workers in the workforce.

TABLE 18

Inter-industry Comparison Of Labor Quality Indicators (Data Represent Percentages Of The Respective Employment Category)

	Plastics			Iron & Steel			Manufacturing		
	'58-66	'67-74	'75-80	'58-66	'67-74	'75-80	'58-66	'67-74	'75-80
Measures of Workforce Experience Levels									
Proportion of Production Workers who are:									
Females	15.5%	21.3%	20.5%	2.1%	2.8%	3.5%	23.6%	25.9%	27.7%
25-44 years-old	52.9	52.7	51.3	48.6	43.6	44.9	48.1	44.4	45.7
55 + years-old	12.0	11.3	11.2	16.4	17.3	16.7	15.0	15.4	14.4
Proportion of Nonproduction Workers who are:									
Females, Nonclerical	19.1	22.8	23.9	10.1	13.1	16.3	17.8	20.0	26.6
25-44 years-old	57.6	51.4	51.7	48.6	46.0	49.2	50.1	47.3	49.8
55 + years-old	10.5	11.1	14.3	14.9	14.8	15.8	13.2	13.5	13.9
Measures of Technical Expertise Levels in the Workforce									
Proportion of Production Workers who:									
Are High School graduates	32.5	46.4	52.6	27.0	38.4	48.6	27.8	38.3	45.4
Have Completed One Or More Years Of College	9.2	10.5	14.2	5.4	7.2	11.5	6.3	8.3	12.6
Are Craftsmen or Operatives	87.4	90.4	88.9	77.2	82.8	83.9	88.6	89.2	87.8
Proportion of Nonproduction Workers who:									
Have Completed Four Or More Years Of College	31.7	33.0	38.8	18.6	21.3	26.8	20.2	23.6	28.8
Are In Professional Or Technical Occupations	42.3	43.6	39.7	27.7	30.9	29.6	27.2	29.5	28.8

SOURCE: Office of Business Analysis, U.S. Department of Commerce.

below the manufacturing average in all periods, though higher than found in iron and steel. Nevertheless, females in nonclerical, nonproduction jobs -- covering management, research, and similar technical occupations -- made up a relatively high proportion of nonproduction worker employment in the plastics industry -- well above the pattern in iron and steel, but slightly below the all-manufacturing average.

Both production and nonproduction workers in the 25-44 year-old age group -- those most likely to be at the productive peak of their careers -- comprised significantly higher proportions of the workforce in the plastics industry. Workers in the oldest age category, 55 years and over 11/, made up a smaller segment of the plastic industry than of either iron and steel or all-manufacturing.

Workers in the plastics industry also tended to possess outstanding levels of technical expertise, as indicated in the bottom half of Table 18. Production workers in this industry are more highly-educated, with higher percentages of both high school completion and college experience 12/ 13/. Workers in highly-skilled craftsmen or machine

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11/ See footnote 9.

12/ The term "college experience" here is used to describe workers with one or more years of college.

13/ See footnote 8.

than in iron and steel, and slightly greater proportions than are found in manufacturing overall.

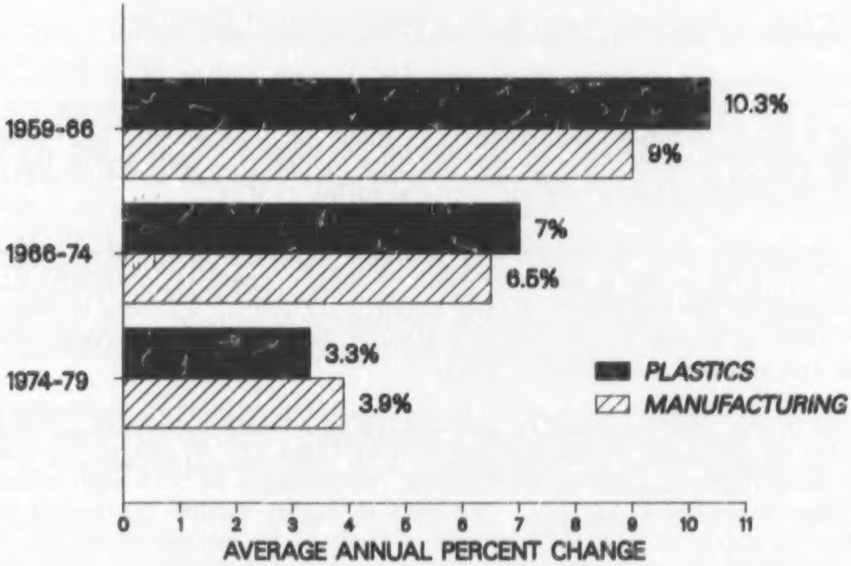
Finally, the technical expertise of nonproduction workers in the plastics industry is shown to be outstanding in the last two lines of Table 18. By 1980, nearly 40 percent of nonproduction workers had at least acquired college degrees, compared to 27 percent in iron and steel and 29 percent in all-manufacturing. These high education levels enabled above-average proportions of professional and technical positions to be filled: 40 percent of nonproduction workers in the plastics industry held highly-trained jobs by the late-1970's, as opposed to 30 percent in iron and steel, and 29 percent in manufacturing overall.

C.3 Labor Cost: Trends in Worker Compensation

Annual compensation per employee in the plastics and synthetic materials industry was on average 18 percent higher than overall manufacturing during the 1958-80 period. In 1958, the average employee in the industry earned $6,310, compared with $5,221 in all-manufacturing. By 1980, the average employee in the industry earned $25,970, compared with $20,017 in manufacturing.

FIGURE 26

Compensation Per Worker In The Plastics And Synthetic Materials Industry And The Manufacturing Sector



SOURCE: Office of Business Analysis, U.S. Department of Commerce.

Compensation Levels Rose Dramatically After 1966 . . .

Figure 26 shows that, prior to 1966, compensation per worker in the plastics and synthetic materials industry grew at an annual rate below that of all manufacturing. For

Compensation Levels Rose Dramatically After 1966 . . .

Figure 26 shows that, prior to 1966, compensation per worker in the plastics and synthetic materials industry grew at an annual rate below that of all manufacturing. For production workers, the growth rate between 1959 and 1966 was roughly equivalent to all-manufacturing: 3.9 percent versus 4 percent; but growth in compensation per nonproduction worker lagged manufacturing: 1.9 percent vs. 3.6 percent.

After 1966, compensation per worker in the plastics industry grew at a faster rate than in manufacturing for all worker classes. In addition, compensation per production worker grew faster than that for nonproduction workers in all periods. In dollar values, however, Table 19 demonstrates that nonproduction workers received higher compensation than production workers.

TABLE 19

Annual Compensation Per Employee

	1958	1966	1974	1980
Production Workers				
Plastics	$5,253	$7,221	$12,518	$23,443
Manufacturing	4,601	6,387	12,554	17,900
Nonproduction Workers				
Plastics	8,851	10,905	18,745	31,560
Manufacturing	7,132	9,894	15,995	25,455

SOURCE: Office of Business Analysis, U.S. Department of Commerce.

. . . But Their Impact Was Offset By Productivity Gains

Compensation per worker interacts with labor productivity levels to determine unit labor cost. Table 20 demonstrates that the relatively high rates of growth in

TABLE 20

The Interplay Between Productivity, Unit Labor Costs, And Compensation Per Worker (Average Annual Percent Changes)

	Compensation Per Worker	Output Per Worker	Unit Labor Cost
Plastics:			
1959-66	3.3%	3.6%	-0.2%
1966-74	7.0	6.6	0.8
1974-79	10.4	6.1	4.4
Manufacturing:			
1959-66	3.9	3.2	0.7
1966-74	6.5	2.4	4.1
1974-79	9.0	2.0	7.0

SOURCE: Office of Business Analysis, U.S. Department of Commerce compensation per worker in the plastics industry had a relatively small effect on unit labor costs because of the industry's outstanding labor productivity growth. In each interval, compensation growth in plastics was quite close to the all-manufacturing growth rate; but the industry's unit labor costs grew only half as fast as in manufacturing, because of the industry's excellent productivity growth.

Compensation Shifted From "Take Home Pay" To "Fringe Benefits"

These increases in compensation paid by the plastics and synthetic materials industry were not reflected entirely in workers' paychecks. In 1958, nine out of every ten dollars of labor compensation were paid directly to workers as payroll; but by 1980 workers were paid directly less than eight of every ten dollars of total compensation. Table 21 shows the relative shift in major compensation components over time.

The rise in importance of supplemental compensation partly reflects increases in legally-mandated employer costs: Social Security payments, Workmen's Compensation, and unemployment insurance. The remainder of this growth was due to increases in programs voluntarily or contractually supplied by employers: insurance programs, private pension plans, and supplemental unemployment benefit funds.

TABLE 21

Percent Distribution Of Labor Compensation — All Workers

Year	Compensation	Payroll	Total Supplements	Required	Voluntary
1958	100.0%	89.5%	10.5%	2.2%	8.3%
1966	100.0	88.2	11.8	3.8	8.0
1974	100.0	83.5	16.5	5.3	11.3
1980	100.0	80.2	19.8	5.9	13.9

SOURCE: Office of Business Analysis, U.S. Department of Commerce

Over the 1958-80 period, supplemental compensation nearly doubled in importance, rising from 11 to nearly 20 percent of labor compensation. Up to 1966, total supplements were growing at an ten percent annual rate; and between 1966 and 1974, at better than 13 percent yearly. After 1974 the growth rate of supplemental labor compensation remained at roughly 12.5 percent per year.

As might be expected, the trends in supplemental compensation differ among occupational classes within the industry. Non-wage compensation grew at a faster rate for production workers than for nonproduction workers until 1974, when the pattern reversed (see Table 22). By 1980, the proportions for production and nonproduction workers had risen to the same level, roughly 24 percent of total compensation.

TABLE 22

Average Annual Growth In Supplemental Compensation

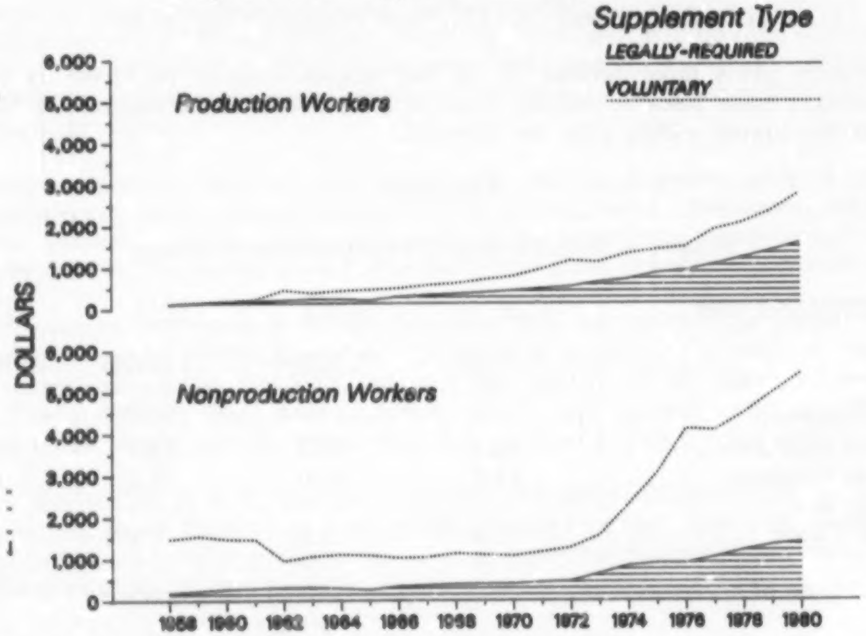
Period	Production Workers	Nonproduction Workers
1959-66	16.2%	3.0%
1966-74	12.4	11.7
1974-79	12.9	15.5

SOURCE: Office of Business Analysis, U.S. Department of Commerce

Figure 27, below, points to voluntary components as the source of much of the growth in supplemental compensation during the 1970's. For both production and nonproduction workers, the bulk of non-wage compensation growth came in the form of fringe benefits beyond those legally-mandated. For production workers, those voluntary supplements grew from 52 to 64 percent of supplements throughout the 1958-80 period. For nonproduction workers the proportion fluctuated between 70 and 89 percent during the interval.

FIGURE 27

Components Of Supplemental Compensation



SOURCE: Office of Business Analysis, U.S. Department of Commerce.

What types of voluntary fringe benefits was the plastics and synthetic materials industry supplying? The following tables show the trends for both types of workers:

TABLE 23

Voluntary Supplements: Production Workers

Compensation type	1958	1966	1974	1980
Total..................	100.0%	100.0%	100.0%	100.0%
Life, Accident & Health Insurance	55.3	60.2	51.0	49.6
Private Pension Plans, Vacation & Holiday Funds */	35.3	35.8	45.7	47.3
Savings and Thrift Plans	9.5	4.0	3.3	2.8

*/ Vacation and Holiday Fund estimates were not available separately for all years; however, data for 1966 and 1974 indicate that they comprised 3.3 and 2.6 percent respectively, of voluntary supplementary compensation paid to production workers in this industry.

SOURCE: Office of Business Analysis, U.S. Department of Commerce

Insurance plans have tended to be the largest benefit received by production workers; pension plans became equally important by 1980. Contributions to Savings and Thrift Plans fluctuated widely over the interval.

TABLE 24

Voluntary Supplements: Nonproduction Workers

Compensation type	1958	1966	1974	1980
Total.................	100.0%	100.0%	100.0%	100.0%
Life, Accident & Health Insurance	26.9	41.3	33.7	27.0
Private Pensions........	69.8	55.0	57.2	62.2
Savings and Thrift Plans	3.4	3.7	7.7	10.8

SOURCE: Office of Business Analysis, U.S. Department of Commerce

Pension plans are a uniformly more important part of nonproduction workers fringe benefits than any other component. Premiums for Life, Accident, and Health insurance programs ranked second. A significant "fringe" for nonproduction workers was employer contributions for Savings and Thrift Plans, which include incentive awards and employee stock purchase plans.

Summary

Following a 1958 to 1966 growth spurt which added 50,000 workers to the payrolls -- a five percent average annual growth rate — employment in the plastics and synthetic materials industry decelerated, then declined slightly, to end the period in 1980 with 151,600 workers, just below the 1966 level. Nonproduction and production workers were affected equally by this slowdown. Average hours-worked per production worker moved even further above the all-manufacturing average during this period, and labor productivity improved significantly: from a 3.6 percent annual rate in the 1959-66 interval, productivity rose to a 6.6 percent annual rate between 1966 and 1974 and grew 6.1 percent annually thereafter.

The drop-off in employment growth after 1966 followed a period of intensive investment in plant and equipment, suggesting an industry move toward highly-automated plants with state-of-the-art equipment. Capital per worker increased, reaching by 1980 a level twice that of 1958. In manufacturing, capital per worker in 1980 was up by 50 percent over its 1958 level.

By 1980, females accounted for one-third of the workforce in plastics and synthetic materials; as in all-manufacturing, they held mostly nonproduction jobs. 45 percent of the workforce was under 35 years of age by 1980, with the 14-24 year-old cohort accounting for most of the growth. All of the employment growth occurred among the youngest and oldest worker classes.

Trends in educational attainment in the workforce closely followed those of all-manufacturing. By 1980 only 25 percent of the workforce had no high school diploma; the number of workers with college experience had risen by one-third. Nonproduction workers had increasingly above-average educational levels, complementing the increases in capital sophistication.

Among production workers, only craftsmen had employment growth after 1966. The bulk of growth came among nonproduction occupations: managers, laborers, and clerical jobs. Indicative of the technical nature of the workforce, professional workers in plastics and synthetic materials were twice the proportions found in all-manufacturing.

Compensation per worker in the industry was 18 percentage points above all-manufacturing over the 1958-80 period. In 1980, the average worker in plastics and synthetic materials earned $25,970; the average worker in all-manufacturing earned $20,017. The relatively high compensation levels and growth rates enjoyed by the industry had little effect on unit labor costs, due to labor productivity gains.

Over the entire 1958-80 period, supplemental labor compensation in the plastics industry nearly doubled, from 11 percent to 20 percent of total labor compensation. As in all-manufacturing, voluntary components of supplemental compensation were source of much of this growth in "fringe" benefits.

D. ENERGY AND MATERIALS INPUTS

D.1 Industry Intermediate Purchases

The plastics and synthetic materials industry is an unique example of a "pass-through" industry. All materials and energy purchased are intermediate products of the economy and almost all products sold are intermediate products, used in the further production of finished goods by other industries. The plastics industry is also unique in that its goods and services purchased are composed of as much as 57 percent energy and energy products, but the majority of this energy input is classified as a feedstock to the production process, a material input.

There are four major classifications of intermediate inputs to the industry: direct energy purchases — electricity, diesel fuel, etc. used for heat, power, lighting, and transportation; energy feedstock purchases -- mainly composed of the energy products ethylene and ethane used to create plastic and synthetic materials; petrochemical feedstock purchases -- energy-intensive chemical products also used to create plastics and synthetic materials; and all other materials inputs — glass, paints, other services industry purchases used in the process of creating products of the plastics and synthetic materials industry.

Only the direct energy purchases are commonly referred to as energy inputs, while energy feedstocks and petrochemical feedstocks are both referred to as material inputs. 1/ This dichotomy in energy input classification highlights the different functional uses and substitution patterns of these energy product inputs. For example, feedstocks must normally be increased or decreased in direct proportion to industry output, because the technology which converts feedstock into plastics and synthetic materials is characterized by fixed proportions. On the other hand, direct energy inputs can be conserved either through efficiency improvements (e.g., heat recycling) or by replacing it with labor, capital, or materials (e.g., insulation).

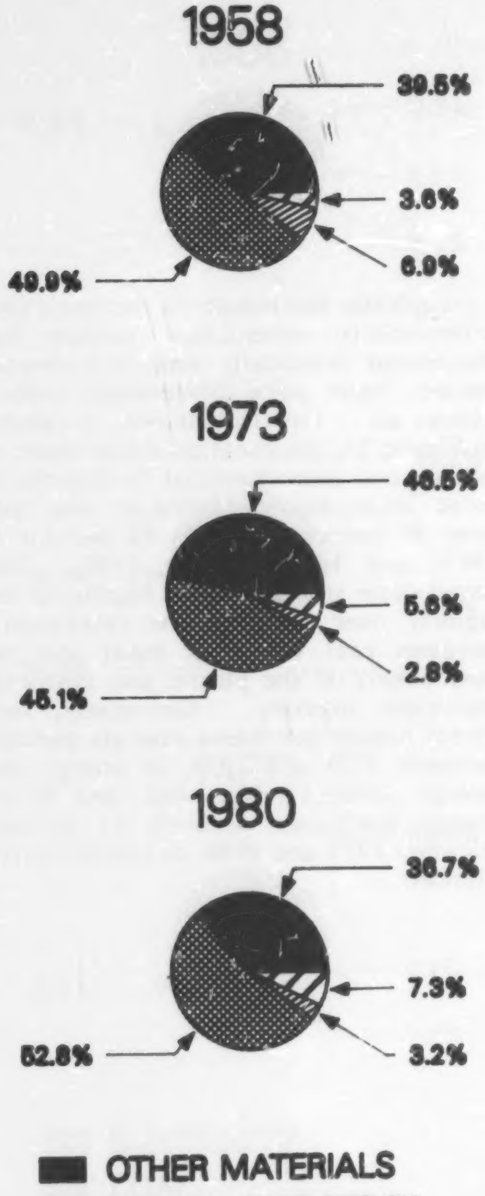
1/ A thorough discussion and flowchart of the energy and petrochemical feedstock process as it relates to the plastics industry are contained in Section D.5 and Figure 35.

Changes in the plastics industry's intermediate purchase pattern have occurred over the 1958 to 1980 period (see Figure 28). In 1958, less than four percent of the industry's current dollar intermediate purchases was in the form of direct energy, while energy and petrochemical feedstocks represented almost 57 percent and other materials purchased accounted for 40 percent. Major price decreases in energy and energy products after 1958 led the industry to expend less on feedstocks. In 1973, feedstocks represented only 48 percent of the industry's intermediate purchases — almost 16 percent less than the share in 1958. Conversely, direct energy purchases rose to almost six percent of total intermediate purchase — over 50 percent higher than the level in 1958.

With large energy and energy product price increases during the 1973-74 Oil Embargo period and again in 1979-80, direct energy purchases increased, by 1980, to over seven percent of total intermediate input cost and feedstocks increased to 56 percent. Other materials purchased by the industry fell to only 37 percent of intermediate purchases.

FIGURE 28

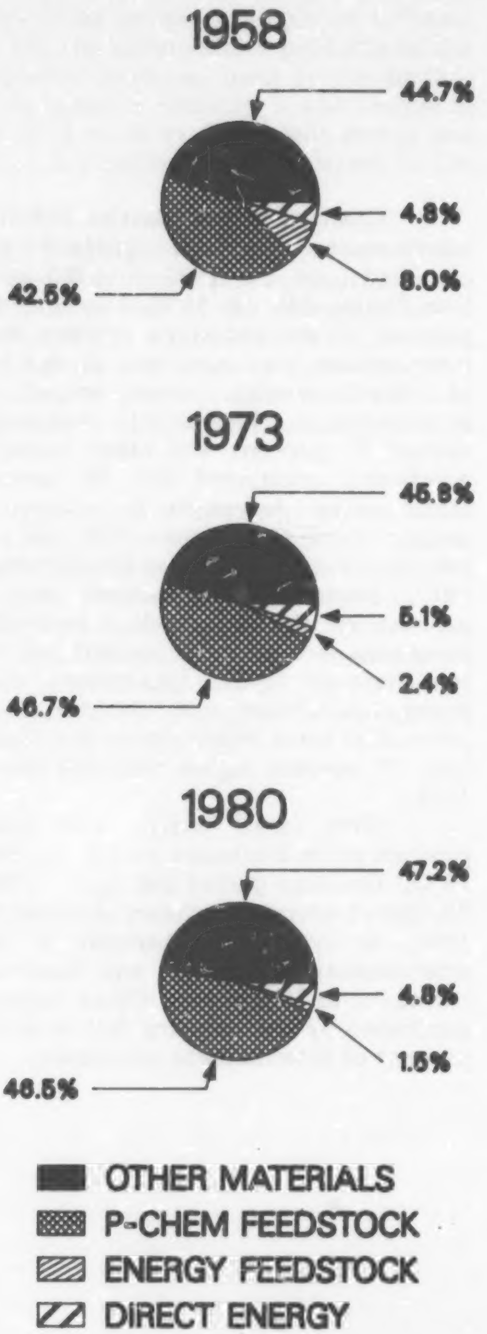
Intermediate Inputs Consumed By Type
(Percent Based On Current Dollars)



SOURCE: Office of Business Analysis, U.S. Department of Commerce.

FIGURE 29

Intermediate Inputs Consumed, By Type (Constant 1972 Dollars)



SOURCE: Office of Business Analysis, U.S. Department of Commerce.

While the industry's current dollar intermediate expenditure pattern has fluctuated drastically over this 23-year period, input price movements explain almost all of the fluctuations. As shown in Figure 29, the constant dollar share of energy and petrochemical feedstocks to total intermediate purchases was just over 50 percent in 1958, 49 percent in 1973, and 48 percent in 1980. This remarkable stability again highlights the rigidity over time of the relationship between real feedstock input and the real output of the plastic and synthetic materials industry. Conversely, real direct energy purchases rose six percent between 1958 and 1973, as energy and energy product prices fell; and direct energy purchases declined six percent between 1973 and 1980, as energy prices climbed.

D.2. Distribution of Direct Energy Consumption by Fuel Type

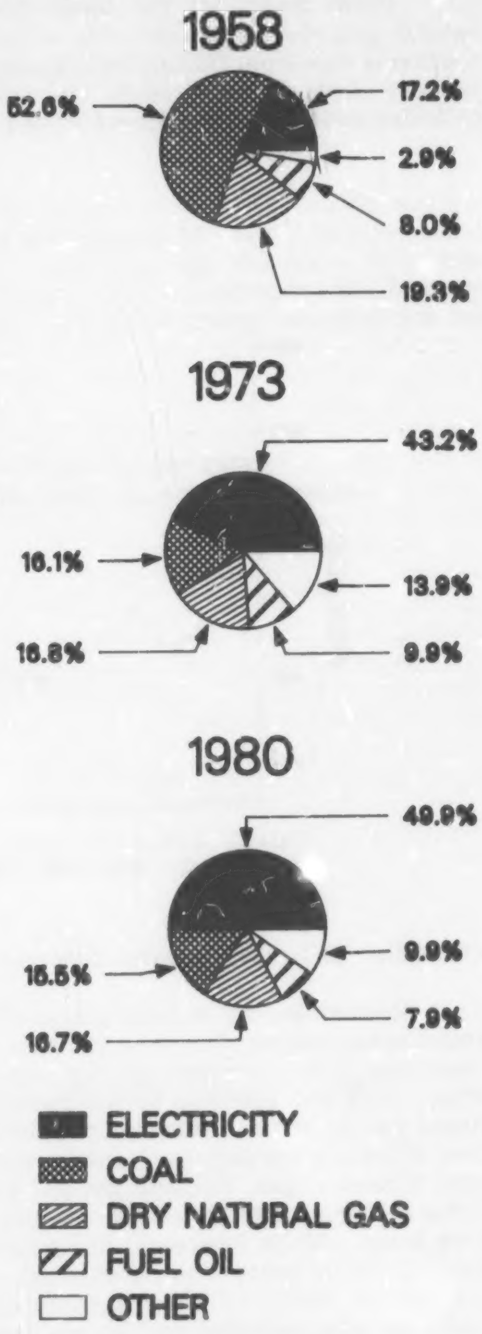
As mentioned in Section D.1, the plastics and synthetic materials industry's total consumption of energy-type inputs (e.g., coal, natural gas, oil, and electricity) consists of two kinds. The first kind includes energy inputs used directly as fuels to produce heat, power, lighting, and transportation. The second kind is composed of oil and natural gas - based inputs (including ethylene, dry natural gas, and liquified gases) used as energy and petrochemical feedstocks. In what follows, we term the energy inputs used for fuel as direct or non-feedstock energy inputs, while the energy inputs used as energy and petrochemical feedstocks are termed feedstock inputs and are treated as a subset of aggregate materials input.

Industry Direct Energy Purchases Are Dominated By Electricity

Electricity accounted for almost 50 percent of the real direct energy inputs (constant 1972 dollars) consumed by the U.S. plastic and synthetic materials industry in 1980 — up almost seven percentage points from the fuel mix in 1973. The consumption of coal and natural gas each accounted for around 16 to 17 percent of the industry's total energy bill, unchanged from the 1973 levels. However, Figure 30 shows that more noticeable changes occurred between 1958 and 1973. In 1958, coal constituted well over one-half of the real direct energy consumed by the industry, while electricity accounted for only 17 percent. Between 1968 and 1973, however, real coal consumption declined 27 percent and constant dollar electricity consumption increased 67 percent, as the industry substituted electricity for coal to produce heat for the production process.

FIGURE 30

Direct Energy Consumed By Fuel Type
(Percent Based On Constant Dollars)



SOURCE: Office of Business Analysis,
U.S. Department of Commerce.

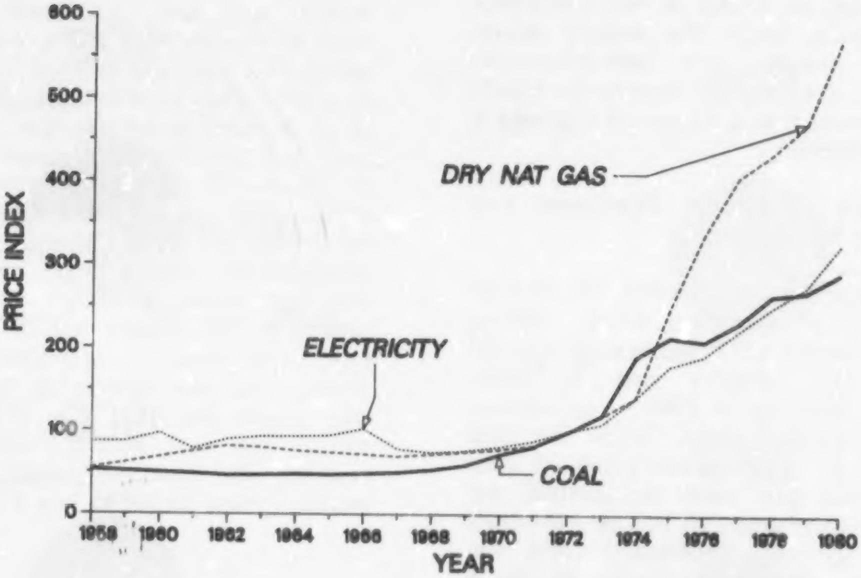
D.3. Prices of Major Direct Energy Inputs

The Industry Has Faced Some Of The Steepest Energy Input Price Increases in U.S. Manufacturing

Price levels for the three most important direct energy product inputs -- dry natural gas, electricity and coal -- are shown in Figure 31. While electricity prices were relatively flat from 1958 to 1975 (rising just over one percent per year), increased costs of primary fuels for electricity (including fuel oil and coal) and the increased cost of pollution abatement equipment forced electricity rates to triple from 1973 to 1980.

FIGURE 31

Selected Direct Energy Input Price Indexes
(1972=100)



SOURCE: Office of Business Analysis, U.S. Department of Commerce.

Meanwhile, dry natural gas prices rose quite rapidly from 1958 to 1962, averaging around seven percent per year, but then remained relatively stable through 1972. In 1973, a minimum price for new gas was set by the Federal Power Commission which raised prices. This was followed by the Natural Gas Policy Act of 1978 which began a series of phased gas decontrol measures that affected gas prices through 1985 and beyond. While these effects were large, they were superceded by price increases allowed on intrastate sales of natural gas. Because gas was available in large quantities in Louisiana and Texas in the 1950's, a majority of the plastics and synthetic materials industry had located in those areas. While interstate gas prices were under price control, intrastate gas (which much of the industry was purchasing) was not. Consequently, by 1978, the year of the Natural Gas Policy Act, the dry natural gas price index (1972=100) faced by the industry had already skyrocketed to 435, well above the U.S. manufacturing average of 325. By 1980, the industry was purchasing dry natural gas almost six times as expensive as that purchased in 1972.

Coal consumed by the industry remained at virtually the same price over the eleven year period between 1958 and 1968. However, by 1972 coal prices had doubled and as mentioned earlier, coal usage by the industry declined markedly. While coal prices did not advance as rapidly as electricity and natural gas prices between 1972 and 1980, external costs (eg. pollution abatement expenditures) discouraged the industry from major fuel switching.

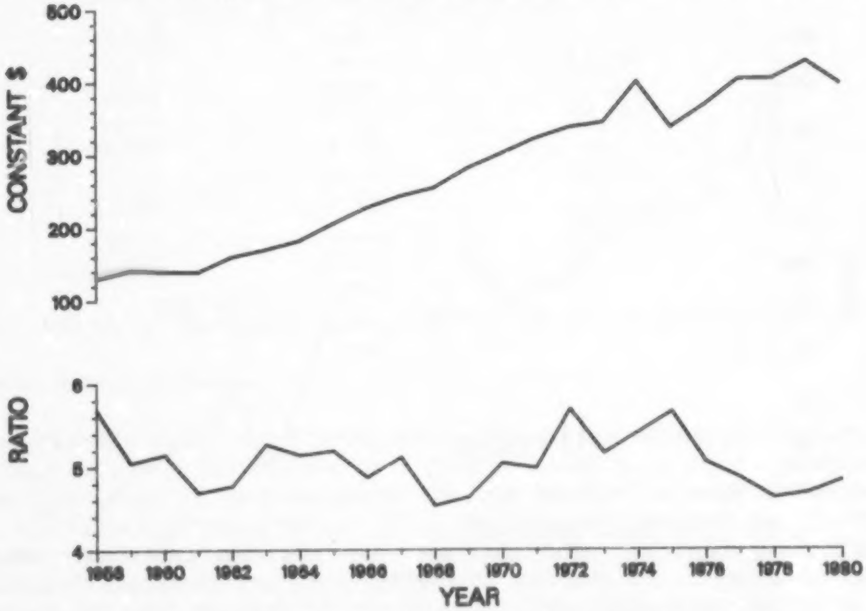
D.4 Direct Energy Input Consumption Levels

Continously Increasing Direct Energy Costs Forced The Industry To Reduce Energy Consumption, And...

The industry's demand for real direct energy inputs into its production function can be classified as price inelastic. For example during the pre - Oil Embargo period, energy input prices rose 61 percent between 1958 and 1973, but the quantity of real energy consumed per unit of output fell by 26 percent. And, in the post - Oil Embargo period, energy input prices almost quadrupled but real direct energy consumption fell only 13 percent.

FIGURE 32

Constant Dollar Consumption Of Direct Energy Inputs
And Direct Energy As A Percent Of Total Real Intermediate Inputs



SOURCE: Office of Business Analysis, U.S. Department of Commerce.

...Significant Improvements In The Industry's Use Of Direct Energy Inputs Began To Appear After 1975.

Real non-feedstock energy consumption stood at $130 million in 1958 and represented almost six percent of all real intermediate inputs to the industry (Figure 32). Real direct energy consumption rose steadily throughout the 1960's but its share of real intermediate (energy plus materials) input dropped to less than 4.5 percent in 1968.

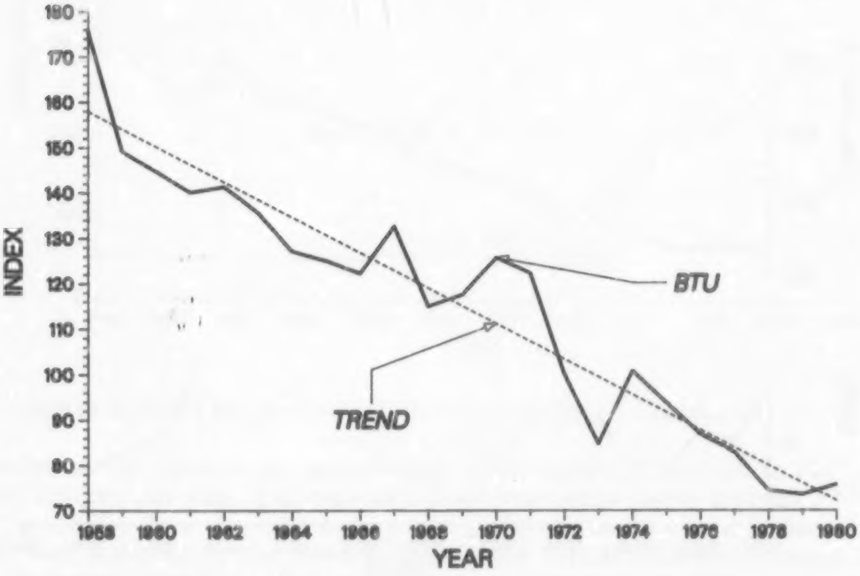
After 1968, the share of direct energy purchases rose almost annually, reaching a peak of 5.7 percent in 1972. During this period the industry was switching from coal to the more expensive inputs of electricity and natural gas. By 1976, though, manifestations of a payoff to the industry's energy conservation activities began to appear. From 1976 to 1978, direct energy inputs as a percent of constant dollar intermediate inputs generally declined to just over 4.8 percent, a level more consistent with the industry's historical trend.

D.5 Efficiency In The Use of Direct Energy Inputs

This trend of decreasing real direct energy consumption can also be seen in the industry's energy efficiency index in Figure 33. In 1972 the industry used 42,000 BTU's per constant dollar of output. Indexing this value to 100, we see that, between 1958 and 1980, the industry has, with a few exceptions, shown a continous year-to-year decline in real direct energy use per unit of real output, declining at an average annual rate of almost three percent per year. And energy used for heat, power, lighting, and transportation has been reduced signficantly since 1974 by exploiting continuous process innovations and other energy efficient technologies. In addition, the industry has recently adopted new direct energy-saving processes such as a new method for producing low density polyethylene.

FIGURE 33

Direct Energy Efficiency Index
BTU's Per Unit Of Constant Dollar Output
(1972=100)



SOURCE: Office of Business Analysis, U.S. Department of Commerce.

Non-Feedstock Energy Efficiency Is Directly Related To Industry Output Levels And Growth, And...

Table 25 demonstrates that the minor fluctuations seen in Figure 33 relate very strongly to business cycle movements in the industry. In almost all cases, an economic downturn has caused a concomitant rise in the number of BTU's used per dollar of output compared with a preceeding economic peak. In the four cases since 1958, the industry's energy efficiency decreased an average of six percent in the trough year compared with the previous peak. In addition, both the peak-to-peak and trough-to-trough series show consistent declines in energy input consumption per unit of output over the 1958-1980 period. These declines were particularly strong in the post-embargo years of 1975, where the industry's energy intensity had declined almost 6 percent per annum from the previous trough, and 1979, where the energy intensity had declined over 6 percent per annum from the previous peak.

TABLE 25

BTU's Of Direct Energy Inputs Per Dollar Of Output
(1972 Dollars)

Year	Peak	Average Annual Change, Peak-To-Peak	Trough	Average Annual Change, Trough-To-Trough
1959	62,600	------	------	------
1960	------	------	63,500	------
1966	51,300	-2.8%	------	------
1967	------	------	55,700	-1.9%
1968	48,300	-2.9%	------	------
1970	------	------	52,800	-1.8%
1974	42,300	-2.5%	------	------
1975	------	------	39,400	-5.7%
1979	30,900	-6.1%	------	------

SOURCE: Office of Business Analysis, U.S. Department of Commerce.

...To Capital Turnover Rates.

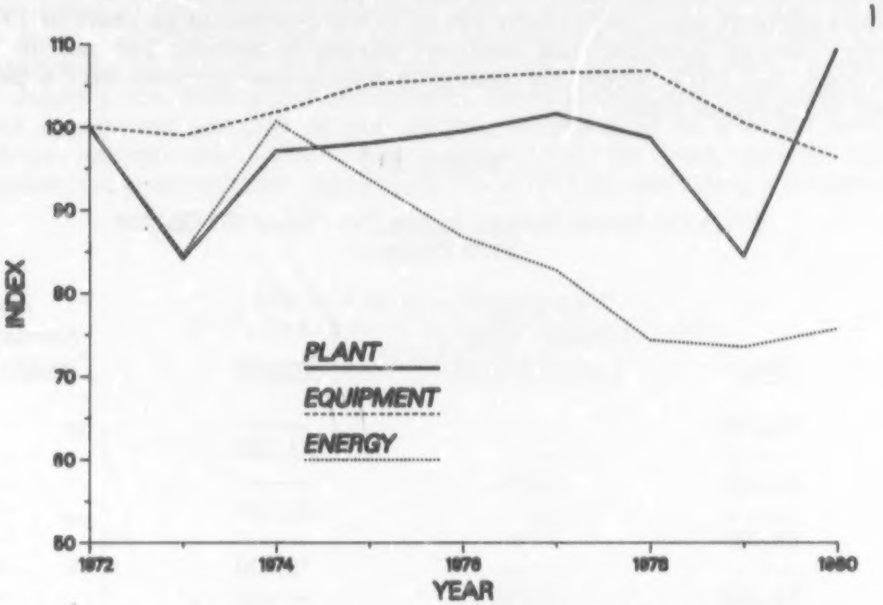
The industry shows a promising future for energy efficiency improvements, but those savings may only be realized by a quicker turnover in capital equipment. While there was not as great an inducement for the industry to seek increasingly energy efficient capital equipment prior to 1973, the industry certainly had to factor rising energy costs into capital purchase decisions since then. Figure 34 shows the proportion of the industry's real plant and equipment which was less than 5 years old during 1972-80 as a percent of all plant and all equipment. This percentage has been indexed to 1972=100. In 1972, just under 35 percent of equipment was under 5 years old and 15 percent of structures was under five years old.

Figure 34 demonstrates that there is an obvious and important correlation between the growing share of new capital from 1973 through 1978 and the growth in energy efficiency that the industry experienced from 1974 through 1978. Moreover, after 1978 when the industry's equipment turnover slowed and the proportion of new industry equipment stock decreased, energy efficiency improvements stopped, and remained relatively level at around 31,000 BTU's per constant dollar of industry output. Given this

historical relationship, one can expect to see a continuation in direct energy efficiency improvements once the industry resumes replacing old capital with new at its pre-1979 rates.

FIGURE 34

Direct Energy Input Efficiency Index And New Capital Indexes Compared (1972=100)



SOURCE: Office of Business Analysis, U.S. Department of Commerce.

D.6 Materials Inputs and Prices

Numerous Petrochemical Feedstocks Dominate Industry Inputs, And...

The plastic and synthetic materials industry purchases three types of feedstocks which can be classified by stage of refinement (see Figure 35). The first type -- raw energy products (natural gas, natural gas liquids and petroleum liquids) -- are purchased directly from the petroleum and natural gas industry and from the petroleum refining industry. These raw energy products are then used by the industry as an energy feedstock, and are classified as material inputs to the plastics industry.

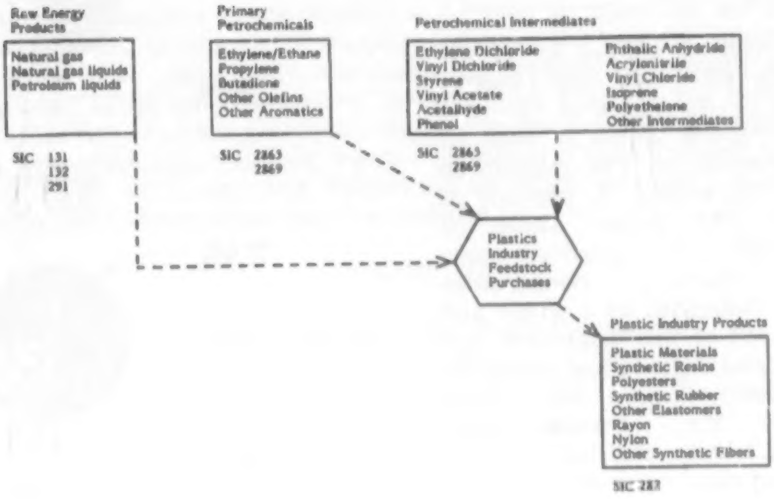
The industrial organic chemical industry (SIC 2865, 2869) also purchases these raw energy products from the petroleum and natural gas industry and processes them into primary petrochemicals. These primary petrochemicals include ethylene, propylene and butadiene. Some of these primary petrochemicals, particularly ethylene, are energy products since they can be used as direct substitutes for direct energy inputs; others are classified as non-energy organic chemicals. Both, however, are purchased by the plastics industry, used as energy and petrochemical feedstocks, and are classified as material inputs to the plastics industry.

FIGURE 35

Energy/Petrochemical Feedstock Process

FIGURE 35

Energy/Petrochemical Feedstock Process


Raw Energy Products
Natural gas
Natural gas liquids
Petroleum liquids
SIC 131
132
291
Primary Petrochemicals
Ethylene/Ethane
Propylene
Butadiene
Other Olefins
Other Aromatics
SIC 2863
2869
Petrochemical Intermediates
Ethylene Dichloride
Vinyl Dichloride
Styrene
Vinyl Acetate
Acetalhyde
Phenol
Phthalic Anhydride
Acrylonitrile
Vinyl Chloride
Isoprene
Polyethelene
Other Intermediates
SIC 2865
2869
Plastics Industry Feedstock Purchases
Plastic Industry Products
Plastic Materials
Synthetic Resins
Polyesters
Synthetic Rubber
Other Elastomers
Rayon
Nylon
Other Synthetic Fibers
SIC 282

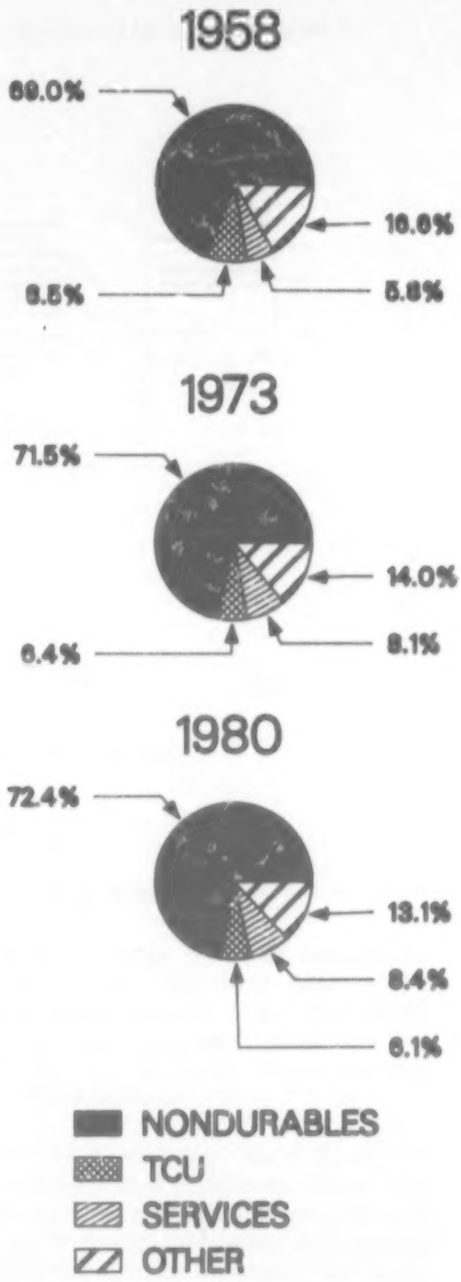
The industrial organic chemical industry also processes these primary petrochemicals into higher order petrochemical intermediates. These petrochemical intermediates include a number of products as listed in Figure 35. All of these products, while petrochemical feedstocks, are classified as non-energy organic chemicals. They are purchased by the plastics industry, used as a feedstock, and are also classified as material inputs to the plastics industry.

Real materials inputs 2/ to the plastics and synthetic materials industry are dominated by purchases of ethylene and refined ethylene products used as chemical feedstocks to the production process. In 1958, almost 70 percent of the constant 1972 dollar value of materials inputs to plastics was purchased from nondurables manufacturing industries as a whole and almost 70 percent of this originated just from the industrial organic and inorganic chemicals industry (Figure 36). Real inputs from the transportation, communication, and utilities sectors represented over eight percent of industry purchases in 1958, while purchases of services accounted for almost six percent.

As ethylene prices declined throughout the 1960's however, industrial chemical purchases grew to more than 50 percent of the industry's real material inputs by 1973. Meanwhile, industry purchases from the service sector also increased and represented over eight percent of constant dollar inputs by 1973.

FIGURE 36

Total Materials Inputs
Consumed By Sector
(Percent Based On Constant Dollars)



SOURCE: Office of Business Analysis, U.S. Department of Commerce.

2/ The term materials is used throughout this report and, unless otherwise noted, includes all materials and services consumed by the industry, including energy used as a feedstock but not direct energy inputs. The term intermediate input includes both materials and direct energy inputs.

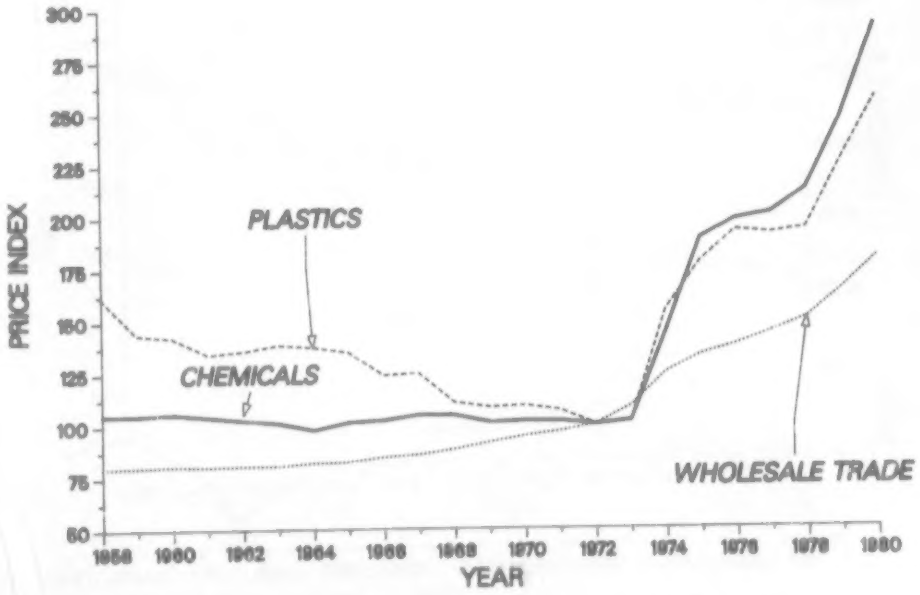
Following the post-Oil Embargo period, rapidly rising natural gas and petroleum product prices drove the share of industrial chemicals consumption to almost 60 percent of the industry's 1980 current dollar materials bill compared with less than 56 in 1958. But, the real (constant 1972 dollar) share remained relatively stable at 50 percent — a reflection of the plastics industry's technology which features a relatively fixed proportions relationship between the volume of real petrochemical inputs used by the industry and the volume of real output it produces. Figure 36 shows that the real 1980 shares of overall nondurables manufacturing and service industry inputs were also virtually unchanged from their 1973 values.

...Increases In Their Prices Have Raised Aggregate Materials Input Prices Faced By The Industry To Some Of The Highest Levels in U.S. Manufacturing.

The largest suppliers to the plastics and synthetic materials industry -- industrial organic and inorganic chemicals -- sharply increased the price of their products since 1973 (see Figure 37). Historically, the industrial chemicals industry accounted for at least 48 percent of all real materials inputs to the plastics and synthetic materials industry and thus have had the greatest influence on the overall price which the industry paid for its aggregate real material input. Industrial chemicals had very stable prices from 1958 through 1972, and this helped offset price increases to the plastics and synthetic materials industry from its other suppliers.

FIGURE 37

Major Materials Input Price Indexes
(1972=100)



SOURCE: Office of Business Analysis, U.S. Department of Commerce.

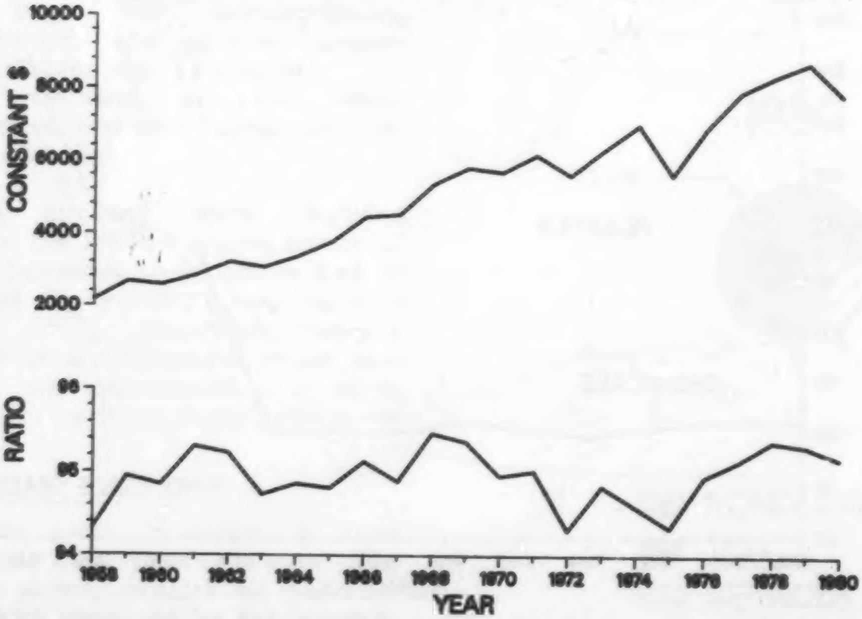
Beginning in 1973, however, prices of industrial chemicals as well as those of plastic materials and resins (an intraindustry input) began to rise rapidly due to the amount of embodied energy in these products. With more stable oil prices in the 1976-1978 period, though, the prices of these two major materials inputs also stabilized. But, when the second round of large oil price increases came in 1979 and 1980, the plastics and synthetic materials industry experienced another round of large price increases from these two major materials suppliers. Since 1973, industrial chemicals prices rose an average of over 16 percent per year and pulled the overall materials input price index to a level of 250 (1972=100) by 1980. As a result, the aggregate materials input price increases absorbed by the plastics and synthetic materials industry were among the highest faced by any U.S. manufacturing industry. Its 1980 materials price index of 250, for example, contrasts with an all-manufacturing aggregate materials input price index of 202.

D.7 Materials Consumption Levels and Efficiency

Real materials inputs in 1958 stood at $2.1 billion and represented almost 94 percent of total constant dollar intermediate inputs to the industry (Figure 38). These inputs remained a relatively stable 94 percent of total intermediate inputs throughout the late 1960's and early 1970's. Beginning in 1976, however, real materials inputs as a percent of total constant dollar intermediate inputs rose to 95 percent and have remained over 95 through 1980.

FIGURE 38

Constant Dollar Consumption Of Materials Inputs
And Materials As A Percent Of Total Real Intermediate Consumption



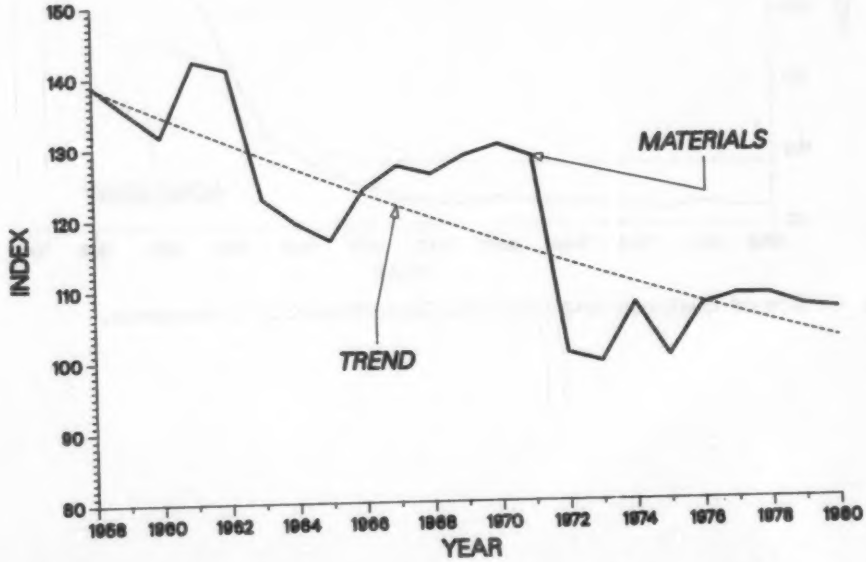
SOURCE: Office of Business Analysis and Bureau of Economic Analysis, U.S. Department of Commerce.

The Industry Shows Impressive Materials Efficiency Gains, 1958-73, But Potential May Have Been Reached.

Figure 39 presents a materials efficiency index that has been calculated as the ratio of constant dollar materials inputs used by the plastic and synthetic materials industry to its constant dollar output and then indexed to 1972=100. Over the entire 23-year period between 1958 and 1980, the industry has experienced a one-percent average annual decrease in the amount of real materials inputs required for each constant dollar of output, compared with about half that recorded for manufacturing industries overall. Figure 39 shows that the industry has recorded some very impressive materials efficiency gains between 1958 and at least though 1973. Beginning in 1973, however, the industry improvements began to slow and after 1975 lost ground; thus, showing signs possibly of having reached a maximum efficiency level -- especially in its use of materials. By 1980, the efficiency index stood at 106 compared with 99 in 1973. Undoubtably, part of the post-1973 stagnation and decline in materials efficiency is due to the combination of business cycle activity and the much reduced rate of economic growth experienced by the industry since 1974 (see discussion in PART III: sections B.3 and B.7).This fact stands out quite clearly in Figure 39.

FIGURE 39

Materials Efficiency Index
(Constant Dollar Materials Consumed Per Unit Of
Constant Dollar Output, 1972=100)



SOURCE: Office of Business Analysis and Bureau of Economic Analysis, U.S. Department of Commerce.

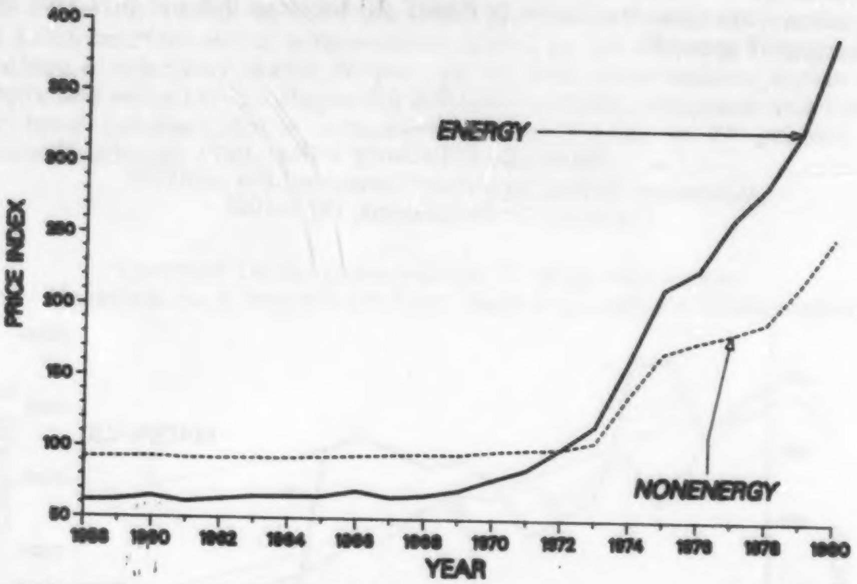
READEX FICHE

D.8 Comparison of Energy and Material Prices

Energy prices increases faced by the industry began to exceed materials price increases in 1967. The nine years prior to 1967, though, show relatively stable prices for both types of intermediate inputs. As seen in Figure 40, more rapid energy price increases began in 1974; and by 1980 the energy price index rose to 390 (1972=100) compared with a materials price index of 250. These differential price movements after 1974 exerted strong influences on factor substitution not only between these intermediate inputs but also among all inputs to plastics and synthetic materials production. These important substitution patterns are examined in detail in section E, which follows.

FIGURE 40

Intermediate Input Price Indexes
(1972=100)



SOURCE: Office of Business Analysis U.S. Department of Commerce.

Summary

The U.S. plastic and synthetic materials industry is one of the most energy intensive industries in the U.S. economy and has had to cope with some of the highest energy and materials input price increases among manufacturing industries. However, between 1958 and 1980, the plastic and synthetic materials industry has recorded well above average economies in its use of direct energy inputs. Similar progress was also made in its use of materials, including feedstock energy inputs, until 1974. Much of this progress seems closely tied to the industry's consistently strong rates of output growth and to its well above average rates of investment in new technically advanced capital. The slowdown in materials efficiency growth after 1974 is probably the result of several factors, including less robust and stable output growth and the substitution of less expensive nonenergy materials for now dramatically more expensive direct energy inputs. Ominously, though, it may in large part be a manifestation of the fact that the industry is approaching a technological limit in its ability to increase the yield obtained from its energy feedstocks. If so, there is some danger in the long-run that the U.S. industry may loose considerable market share both domestically and internationally to such natural gas rich countries as Canada, Mexico, and Saudia Arabia, unless major break-throughs are made in biotechnology research designed to produce feedstocks economically from renewable plant-type resources as a substitute for feedstocks derived from oil and natural gas resources. In the intermediate run, however, the industry should benefit from lower feedstock prices caused by the competition from the new, state-of-the-art petrochemical plants recently established in these countries.

E. INPUT SUBSTITUTION PATTERNS

Technological Innovations And Trends In Relative Input Prices Produce Important Changes In Input Structure, 1958-80

E.1 Patterns in Input Substitution

Some of the most important implications of the analyses in sections A through D are summarized in the input substitution patterns depicted in Figures 41 through 45, and summarized below in Table 26. The seven input ratios shown there are measured in terms of real units — employment for labor and constant-dollar values for capital, direct energy, and materials — and are presented in index form (1958=100). Capital is defined as net plant and equipment less capital used primarily to control pollution. Direct energy is defined as energy inputs used directly for the production of heat, power, lighting, and transportation. Energy-based feedstocks are included in the material inputs.

In each Figure, the shaded area between the (1958=100) index line and the data line highlights the change in actual relative input use (for example, the number of nonproduction workers used per production worker) compared to the proportion that existed in 1958. On the other hand, the dark, straight-line segments represent the peak-to-peak linear trends in relative input usage between selected business cycle output peaks. The first trend segment in each graph defines the growth in relative input usage between the 1959 and 1966 output peaks; the second segment between the 1966 and 1974 peaks; and the third segment between the 1974 and 1979 peaks. The trend lines thus remove the obscuring effects of business cycles and more clearly describe how the plastics industry's long-run input structure was evolving under conditions of full or high production.

TABLE 26

Input Substitution Patterns
Between Selected Output Peaks

(Compound Annual Percent Change)

	Peak-To-Peak Interval		
Input Ratio	1959-66	1966-74	1974-79
Nonproduction Workers: Production Workers	-0.05%	0.05%	1.23%
Fixed Depreciable Capital: Production Workers	-2.53	2.89	4.68
Energy : Production Workers	4.46	6.94	2.35
Energy : Fixed Depreciable Capital	1.89	3.94	-2.22
Materials : Production Workers	2.81	4.19	6.18
Materials : Fixed Depreciable Capital	0.28	1.27	1.44
Energy : Materials	-1.60	2.64	-3.61

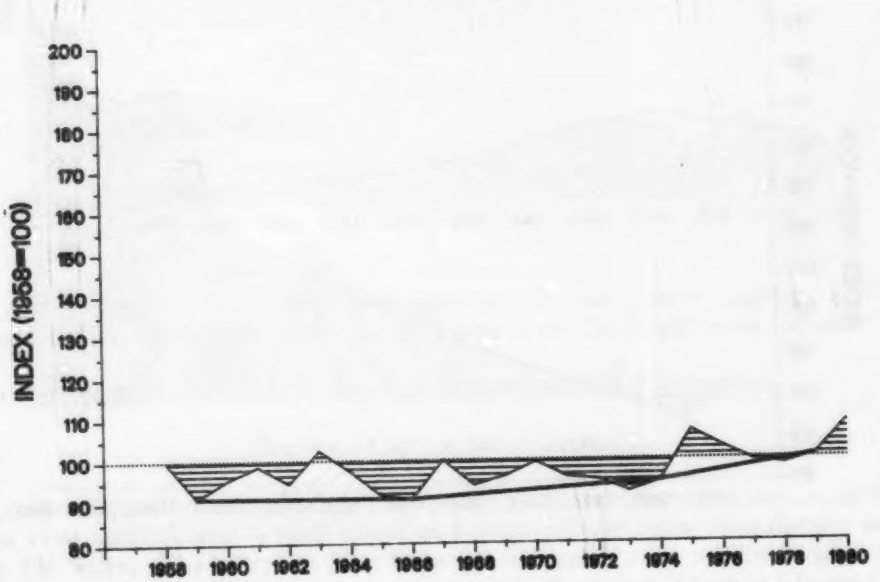
SOURCE: Office of Business Analysis, U.S. Department of Commerce.

NonProduction : Production Worker Substitution...

Figure 41 shows the substitution between production and nonproduction workers. The index of nonproduction workers to production workers stood at 100 in 1958 and 100.7 in 1979 — virtually no change. The trend curve, however, presents a more informative story. Between the 1959 and 1966 output peaks, the nonproduction: production worker index was indeed remarkably stable, with only a slight negative trend of 0.05 percent (compound rate) per year. But, between the 1966 and 1974 peaks, the long-term trend in the ratio turned positive and advanced slowly at the compound rate of just 0.5 percent per year. Between the 1974 and 1979 peaks, however, the rate of substitution of nonproduction workers for production workers accelerated sharply to more than 1.2 percent per year, as the index advanced from 94.7 in 1974 to 100.71 in 1979.

FIGURE 41

Input Substitution Patterns:
Ratio Of Nonproduction Workers To Production Workers
(Index, 1958=100)



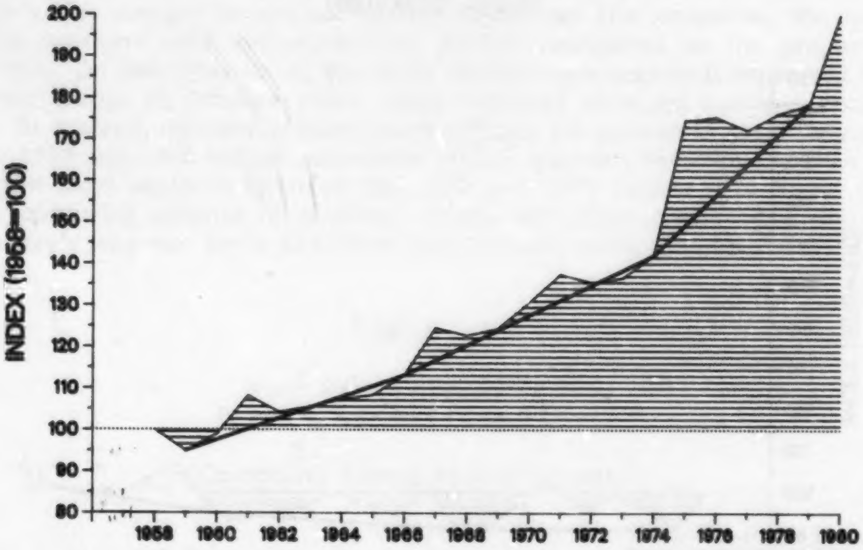
SOURCE: Office of Business Analysis, U.S. Department of Commerce.

Capital : Production Worker Substitution...

Figure 42 describes the rapid substitution of capital for production workers between 1958 and 1980. The long-term trend curve shows that, peak-to-peak, capital was substituted for labor at the rate of 2.5 percent per year between the 1959 and 1966 peaks. The rate of substitution accelerated to 2.9 percent per year between 1966 and 1974 and to 4.7 percent per year between the 1974 and 1979 output peaks. As a result, by the 1979 peak, the quantity of real capital employed in the plastics and synthetic materials industry for each of its production workers was nearly double that employed at the 1959 peak.

FIGURE 42

Input Substitution Patterns:
Ratio Of Capital To Production Workers
(Index, 1958=100)



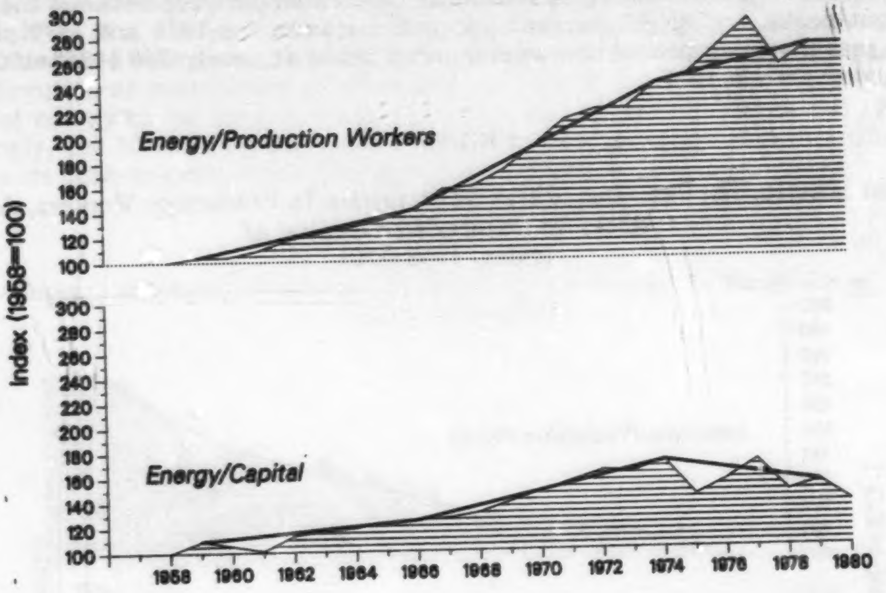
SOURCE: Office of Business Analysis, U.S. Department of Commerce.

Energy : Production Worker Substitution...

Figure 43 (top) demonstrates the rapid growth in the substitution of real direct energy inputs for production workers. By 1979, the index of energy to production workers stood at 270.6 (1958=100) — 161 percent above its 1959 peak output level. The trend curve in Figure 43 (top) shows, however, that the growth in this ratio was not uniform between output peaks. Between 1959 and 1966, real direct energy used per production worker increased at the compound rate of nearly 4.5 percent per year; and it accelerated to almost 7.0 percent per year between 1966 and 1974. Before declining, the ratio peaked at an index value of 291 in 1977. As a result, the peak-to-peak rate of growth declined more than 50 percent to a compound annual rate of just 2.3 percent between 1974 and 1979.

FIGURE 43

Input Substitution Patterns:
Ratio Of Direct Energy To Production Workers, And
Ratio Of Direct Energy To Capital a/
(Index, 1958=100)



a/ Energy here includes only energy used directly for heat, power, lighting and transportation; it excludes energy feedstocks which are included in materials.

SOURCE: Office of Business Analysis, U.S. Department of Commerce.

Energy : Capital Substitution...

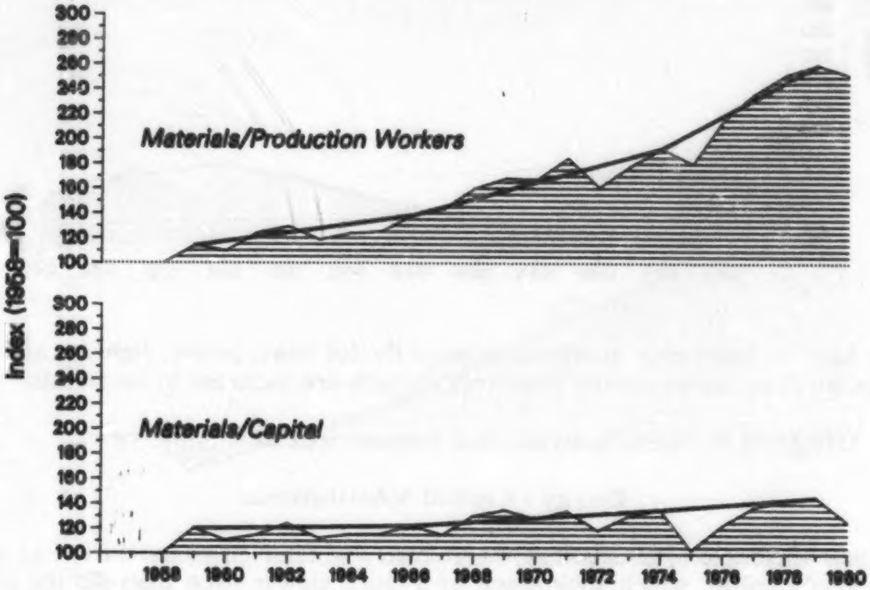
Figure 43 (bottom) illustrates the industry's historical substitution of real direct energy for real capital, which took place at a much slower pace than did the substitution of energy for labor. The index of direct energy to capital rose nearly 40 percent -- from 103.8 in 1959 to 151.6 in 1979. Once again, though, the trend curve in Figure 43 (bottom) demonstrates three very distinct epochs in the industry's long-run input substitution pattern. Between the 1959 and 1966 output peaks, the ratio of direct energy to capital advanced at the compound rate of 1.9 percent per year but at more than double this rate between 1966 and 1974 -- 3.9 percent per year. After the 1973-74 energy crisis, however, the direction of substitution reversed and the industry began substituting capital for direct energy at the compound rate of 2.2 percent per year between the 1974 and 1979 output peaks.

Materials : Production Workers Substitution...

Figure 44 (top) demonstrates the dramatic change that took place in the industry's materials:production worker ratio during the 1958-80 period. Again, three major epochs are evident in the trend curve. Between 1959 and 1966, the industry's use of real materials per production worker increased at the compound annual rate of 2.8 percent. However, the rate of substitution increased to 4.2 percent per year between the 1966 and 1974 output peaks, and to 6.2 percent per year between the 1974 and 1979 peaks. By 1979 the real materials:production worker index stood at nearly 260 (1958=100), or 160 percent higher than in 1958.

FIGURE 44

Input Substitution Patterns: Ratio Of Materials To Production Workers, And Ratio Of Materials To Capital a/
(Index, 1958=100)



a/ Material includes energy feedstocks.

SOURCE: Office of Business Analysis, U.S. Department of Commerce.

Materials : Capital Substitution...

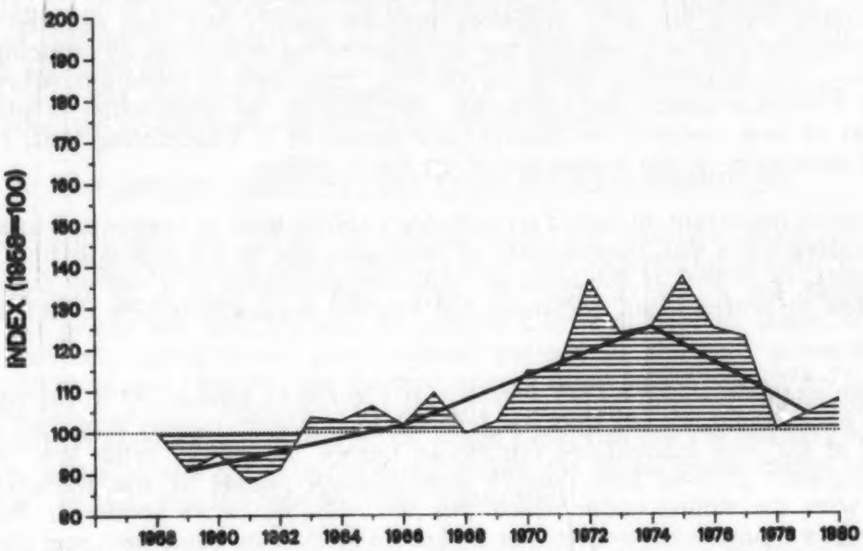
Figure 44 (bottom) shows the industry's substitution of real materials inputs for real capital inputs. As was the case with energy, the substitution of materials for capital evolved at a much slower pace than did the substitution of materials for labor. The materials:capital ratio index stood at 120.1 (1958=100) in 1959 and at 145.5 in 1979. Between the 1959 and 1966 output peaks, the ratio advanced very slowly at the compound annual rate of less than 0.3 percent. Afterwards, however, the industry's long-term substitution of materials for capital accelerated sharply and grew at a relatively constant compound annual rate — 1.3 percent between the 1966 and 1974 peaks and 1.4 percent between the 1974 and 1979 peaks.

Energy : Materials Substitution...

Finally, Figure 45 illustrates the historical evolution in the industry's substitution of real direct energy inputs for real materials inputs. The direct energy:materials ratio index (1958=100) stood at nearly 91 in 1959 and at 104.2 in 1979. The trend curve, however, demonstrates that the industry's relative use of direct energy and materials evolved in dramatically different ways between the three sets of output peaks. Between 1959 and 1966, the energy:materials ratio grew at the compound annual rate of 1.6 percent, compared with more than 2.6 percent between the 1966 and 1974 peaks. But, the the direction of substitution reversed and the industry increased its use of materials per unit of energy at the rate of 3.6 percent per year between the 1974 and 1979 peaks. Interestingly, the industry's peak-to-peak direct energy:materials growth profile closely resembles its peak-to-peak direct energy:capital profile.

FIGURE 45

Input Substitution Patterns: Ratio Of Direct Energy To Materials a/
(Index, 1958=100)



a/ Energy here includes only energy used directly for heat, power, lighting and transportation; it excludes energy feedstocks which are included in materials.

SOURCE: Office of Business Analysis, U.S. Department of Commerce.

E.2 Technical Innovation and Input Substitution [1]

A major factor underlying the evolution of the industry's input structure between 1958 and the early seventies was the great wave of cost-saving technical advances which swept over the industry before 1970. These new innovations included the use of larger, faster, more continuous and more complex equipment in the production of both plastics and synthetic rubber. These machines and equipment greatly automated the production process, reduced labor and materials requirements, and increased energy requirements.

Examples of these capital-embodied innovations include high-speed plastics welders with automatic feed; new machines and mold designs (applied to compression, injection, and blow molding) which made possible fully automatic transfer molding techniques; a new parts stacker which made molding a continuous operation -- from the stocking of materials through, forming, cutting, and stacking the finished product; continuous mixing or warm-up machines which reduced not only labor but also capital requirements; and process control computers which were being used by the industry as early as 1960.

Complementing these capital-embodied innovations, there was the development of new techniques which not only improved product quality but also reduced labor and materials requirements by increasing the accuracy of materials use, by reducing the time of production, and by reducing scrap and rejects. Examples of these innovations include the use of foamed-in-place and ultrasonic vibration in the application of plastics; the introduction of new molding techniques, and advances in calendering (i.e., rolling and smoothing) techniques in the production of synthetic rubber.

It is also important to note that industry's ability both to create and to absorb this great innovative wave was, undoubtably, in large part due to the unusually high quality of its labor input, as judged by the level of education embedded in it and by the proportion of it devoted to professional, technical and kindred occupations (see PART II: Section C.1).

As we examine the pre-1974 segment of Figures 41 through 45 in the light of this technology background, we see that the general trend in each case is very consistent with the nature of the new innovations introduced before the energy crisis era. Moreover, even the distinct 1959-66 and 1966-74 peak-to-peak phases of the trend curves are consistent with the timing under which this technological wave occurred. As we have seen, these new innovations were either embodied in the new equipment and plants which the industry rapidly acquired during the 1960's or they required this new capital to implement them. Between 1958 and 1969, the industry's net stock of real capital, excluding pollution abatement capital, doubled but two-thirds of this took place after 1964 (see PART II: Section A.1).

The dispersion and widespread installation of this new technically advanced capital was undoubtably associated with a substantial period of training and adjustment of the existing input structure, particularly labor, to the more cost effective input structure made possible by the new technology. This adjustment process is revealed in Figures 44 through 45. As discussed above, in each case the change in input structure was more rapid in the 1966-74 period than it was in the 1959-66 period. For example, Figure 42 shows that the ratio of capital to production workers acclerated to a 2.9 percent peak-to-peak compound rate between 1966 and 1974. Moreover, while this new technically advanced capital reduced the input of labor required per unit of output over the entire period (see PART III: Sections B.2 and B.4),it was not until the post - 1966 period that it began to produce both absolute decreases in labor requirements overall (see PART II: Section C.1) and long - term relative increases in nonproduction worker requirements relative to production workers (see Figure 41). In summary, these innovations increased the industry's already unusually high demand for highly-educated technical, professional and kindred workers (see PART II: Section C.2).

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[1] Background on technological developments in the industry was provided by, Technological Trends In Major American Industries, Bulletin No. 1474, Bureau of Labor Statistics, U.S. Department of Labor and by the Office of Chemicals and Allied Products, International Trade Administration, U.S. Department of Commerce.

Finally, as we examine the post-1974 energy substitution patterns in Figures 43 and 44, we note that the rate of substitution of direct energy inputs for labor, capital, and materials either declined between the 1966-74 and 1974-79 output peaks or reversed direction in the case of materials. Given the extraordinary rise in the relative price of energy during this period (see next section), this result was to be expected. However, it is also important to note that after 1977, the industry developed and widely dispersed only one major cost-saving innovation -- a low density method for producing polyethyelene (the largest volume plastics materials). Significantly, though, this new method is reported to reduce energy use by 25 percent, space requirements by nearly 90 percent, and capital investments by 50 percent. Another innovation, which may have contributed significantly to reversal in the direct energy: materials ratio trend curve after 1974, was the industry's development and use of advanced catalytic agents to improve production yield: especially polypropylene production.

E.3 Growth in Relative Input Prices and Input Substitution

A second important factor underlying both the plastics industry's changing technology and input structure since 1958 has been the differential growth in the prices the industry paid to acquire each input type. 2/ Table 27 shows the average annual growth in the prices the industry paid to acquire a unit of capital, labor, energy, and materials services during three peak-to-peak periods -- the two pre-energy crisis subperiods, 1959-66 and 1966-74, and the post-energy crisis subperiod, 1974-79. When we compare the relative input price growth patterns by interval with the corresponding peak input substitution patterns shown above, we would expect to see the industry substituting those inputs whose prices are growing more slowly for those whose prices are growing more rapidly. In fact, this is precisely what transpired.

For example, consistent with the input substitution patterns pictured in Figure 41, Table 27 demonstrates that the price of production workers grew faster than that of nonproduction workers during all three peak-to-peak intervals. Further, consistent with the materials substitution patterns in Figures 44, Table 27 shows that the growth in materials prices was consistently well below that recorded for both production workers and capital.

Similarly, the peak-to-peak direct energy substitution patterns pictured in Figure 43 are consistent with the relative growth rates in the unit prices paid for direct energy

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2/ Undoubtedly, many of the technical innovations discussed in the previous section were also induced by relative input price growth and cost share considerations. However, no attempt is made here to separate pure price induced factor substitution from technology-based substitution. Rather, we seek simply to demonstrate that the industry's factor substitution patterns were economically rational.

inputs versus those paid for nonproduction workers, capital, and materials inputs between 1959 and 1979. This fact is transparent during the 1959 to 1966 interval but not so during the 1966-74 interval. Although the 1966-74 average annual percent change in energy prices exceeded those recorded for the other three inputs (Table 27), either the same (in the case of capital) or a more rapid (in the case of labor and materials) subsitution of energy for these three inputs took place nevertheless (Figure 43 and 45). Though this result seems paradoxical, it is easily explained by noting three facts: (1) most all of the rapid growth in direct energy prices occurred after 1970, and especially during 1973 and 1974 3/; (2) the cost shares of production workers in total cost were between two and three times larger than direct-energy cost shares during 1966-74; as a result, a one percent decrease in the use of labor per unit of output would have reduced unit total production cost two to three times more than a one percent decrease in direct-energy use per unit of output during this period 4/; and (3) part of the more rapid increase in the case of labor and materials substitution after 1966 reflected the fruition of labor-saving and energy-using capital projects begun in prior years. Importantly, Figures 43 and 45 show that during 1974-79, the industry either significantly reduced its long-run rate of direct energy substitution (in the case of production workers and capital) or reversed the direction of substitution (in the case of materials), as double digit direct energy price growth continued to outstrip the price growth of the other three inputs.

Finally, the 1959-66 and 1966-74 peak-to-peak substitution of capital for production worker patterns (Figure 42) is also either consistent with the relative rate of price growth or it can be explained in the same manner as was done above for energy. But, it is apparent that pure relative price growth differences cannot explain the accelerated rate of capital for labor substitution that occurred between the 1974 and 1979 output peaks. This phenomenon can, however, be explained by the fact that the industry's quest to reduce its direct energy costs likely required significant investments in more energy efficient capital. An indirect and unintended by-product of this investment would be an increase in the capital:production worker ratio.

3/ Direct energy prices rose 7.6, 5.8, 18.1, 20.4 and 33.3 percent respectively in the years 1970 through 1974.

4/ Average distributions of total production costs in the plastics and synthetic materials industry among capital, labor, direct energy, and materials inputs over peak-to-peak intervals (1959-66, 1966-74, and 1974-79) are given in PART III: Section B.2.

TABLE 27

Comparison Of Growth Rates In Input Prices During Selected Peak-To-Peak Intervals (Average Annual Percent Change) a/

		Interval	
Input Type:	1959-66	1966-74	1974-79
Capital: b/			
New Capital Investment Price	1.5	5.1	7.7
Tax Offset	-0.3	0.3	-0.1
After-tax Investment Price	1.2	5.4	7.6
After-tax Real Gross Cost Of Capital	1.0	2.3	5.7
Before Tax Adjustment Factor	-0.6	0.0	-0.4
Before-Tax Real Gross Cost Of Capital	0.4	2.3	5.3
Before Tax Price Of Capital	1.6	7.7	12.9
Labor (Compensation/worker):			
Production workers	3.8	6.9	10.0
Nonproduction workers	1.9	6.8	9.3
Direct Energy	-7.1	10.9c/	15.5
Materials (Including Energy/ Petrochemical Feedstocks)	1.1	4.6	8.9

SOURCE: Office of Business Analysis, U.S. Department of Commerce.

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a/ All input price growth measures in the Table are appropriately based on before-tax input prices. The average annual percent change values shown here were computed by the method described in footnote 3 of PART III, except for the two tax related measures in the cost of price of capital calculation. These were computed as the compound rate of growth in the value of each measure between the beginning and ending year of each interval shown in the table.

b/ The before-tax price of capital (P_k) is defined by the formula:

$$P_k = q_k(1-uz-k)((r-w+d)/(1-u))$$

where q_k = the investment price of new plant and equipment and capital to the plastics industry; u = the industry's expected marginal corporate income tax rate on profits earned by the new capital at the point of investment; z = the present value of the depreciation the industry expects to take for tax purposes over the tax service life of the new capital; r = the composite after tax cost of capital from all sources used to finance the investment; w = the rate at which the industry expects to increase its product prices over the planning horizion and represents the industry's ability to pay its future capital costs in cheaper dollars; and d = the expected rate of economic depreciation and represents the loss in asset value due to wear and tear and obsolesence over the

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(footnote b continued)

economic service life of the newly acquired capital.

The price of capital can be decomposed into the product of two parts:

(1) the after-tax investment price -- $q_k(1-uz-k)$

and

(2) the real before-tax gross cost of capital -- $(r-w+d)/(1-u)$.

From this it follows that the growth in the before-tax price of capital consists of:

(1) the growth in the after-tax investment price of capital plus (2) the growth in the real before-tax gross cost of capital.

Part (1) is derived in the first three lines under the price of capital; part (2) is derived in the next three lines; and the resulting growth in the before - tax price of capital is given on line seven of Table 26.

The OBA estimated effective investment tax credit rates for the plastics industry were 0 in 1959, 5.1 percent in 1966, 5.6 percent in 1974, and 8.0 percent in 1979. The 1959, 1966, 1974, and 1979, corporate tax rates were 52, 48, 48 and 46 percent respectively. The present value of depreciation was set at 73.9 cents on a dollar in 1959, 74.5 cents in 1966, 68.8 cents in 1974, and 67.9 cents in 1979. These present value estimates were taken from Jorgenson and Sullivan; Inflation and Corporate Capital Recovery," in C. Hulten (ed.) Depreciation, Inflation, and Taxation of Income from Capital, The Urban Institute, 1981. r is the composite cost of capital described in PART II: Section B.3; w is estimated as a centered 5-year moving average of the percent changes in the industry's annual output price deflator; d is set at .04 for buildings and .12 for equipment and the overall d is obtained as a weighted average of the two economic depreciatin rates, with the weights representing the historical dollar shares of plant and equipment in each year's total investment; and q_k is the industry's annual investment price deflator.

c/ As explained in footnote 3 above, most of this 1966-74 rapid growth in energy prices is attributable just to the years 1973 and 1974.

PART III

PRICES, PRODUCTIVITY, AND COSTS OF PRODUCTION

SINCE 1958

INTRODUCTION

A Model Of Economic Efficiency Among U.S. Industries; But, Can It Survive World Market Competition After The Deregulation of U.S. Energy Prices?

PART II analyzed the important changes which have taken place in the U.S. plastics and synthetic materials industry's use of capital, labor, energy, and material inputs, and the changes in the prices paid for these inputs. PART III synthesizes these changes into a comprehensive but nontechnical description of the evolution of production costs in the plastics and synthetic materials industry during the period 1958-80. This analysis more clearly defines and quantifies the important factors -- both those internal to the production process as well as uncontrollable external factors -- which have determined the industry's unit cost of production over time, and thus determined its current state of economic vitality and competitiveness.

The presentation proceeds as follows. Section A provides a simple explanation of the linkage between competitiveness and the growth patterns in input productivity, input price, and unit total cost of production. A cost-growth accounting framework is developed and then used in Section B to trace the sources of growth in the plastics and synthetic materials industry's non-capital unit cost of production back to the separate contributions of labor, energy, and materials.

Section B analyzes the plastics and synthetic materials industry's historical performance with respect to:

- the relationship between its unit output prices and unit total costs;
- the productivity growth obtained from its inputs -- both total factor and single factor productivity -- relative to that achieved in other selected U.S. manufacturing industries;
- the relationship of its input-specific unit costs of production to its input-specific productivity and price experiences;
- the contribution made to the growth in its non-capital unit total cost of production by each of three broadly-defined noncapital inputs -- labor, energy, and materials -- to its production process; and
- the performance of the plastics and synthetic materials industry in controlling its total input and individual input production costs, compared with the performances of other selected U.S. manufacturing industries.

The data, facts, and analyses presented in PART III should be of special interest to those seeking to understand and evaluate the factors which have contributed to the industry's outstanding efficiency performance.

A. ECONOMIC COMPETITIVENESS AND THE COST OF PRODUCTION

In recent years, the economic vitality of several formerly secure U.S. industries has been placed in jeopardy by either an actual or potential inability to compete in the market place. As a result, we often hear that U.S. industries must achieve higher productivity growth if they are to maintain their competitive position in the world-market environment. But, what is meant by this prescription is not well understood. Most Americans interpret it to mean that labor productivity must increase; when, in fact, improving the productivity growth of some other input may be more critical to the survival of a given industry. For example, productivity in the use of materials inputs is about five times more important than labor productivity growth to the competitiveness of U.S. Plastics and Synthetic Material Industry.

A more fundamental problem, though, is that productivity growth is only part of of the more complete measure of an industry's ability to compete. The more correct and inclusive standard for judging both an industry's productive efficiency and its competitive potential is its unit total cost of production over time. In the final analysis, this is what determines its "affordable" output price. 1/

Under reasonably competitive conditions, the price an industry charges for its product over time will closely mirror its unit total cost of production:

(1) **Unit Total Cost** = Unit Capital Cost + Unit Labor Cost + Unit Materials Cost + Unit Energy Cost.

Accordingly, the rate of inflation in the industry's price will reflect the growth in total input unit cost:

(2) **Growth in Unit Total Cost** =

$$\frac{\text{Capital Cost}}{\text{Total Input Cost}} \times (\text{Growth in Capital Price} - \text{Growth in Capital Productivity})$$

$$+$$

$$\frac{\text{Labor Cost}}{\text{Total Input Cost}} \times (\text{Growth in Labor Price} - \text{Growth in Labor Productivity})$$

$$+$$

$$\frac{\text{Energy Cost}}{\text{Total Input Cost}} \times (\text{Growth in Energy Price} - \text{Growth in Energy Productivity})$$

$$+$$

$$\frac{\text{Materials Cost}}{\text{Total Input Cost}} \times (\text{Growth in Materials Price} - \text{Growth in Materials Productivity}).$$

1/ Depending on the industry, many demand-side factors also affect the ability to compete — the quality of the product, the technology embodied in it, the availability of substitutes, the exchange rate, etc. However, over time the dominant factor will utimately be the price at which the industry can afford to sell its product, relative to the prices either of identical products produced by foreign competitors or of substitute products produced by both domestic and foreign competitors, and still remain in business. In turn the industry's long-run "affordable" output price is determined by the unit cost it incurs to produce it.

The four terms outside of the brackets in formula (2) are called the cost shares for each input and are obtained by dividing the cost for each input by the sum of the costs for all inputs. Moreover, the four bracketed terms in formula (2) represent the growth in unit capital costs, unit labor costs, unit energy costs, and unit materials costs. 2/

The cost-growth accounting formula (2) provides the framework needed to systematically define, measure, and examine the major direct economic factors underlying the historical evolution of an industry's cost structure. In simple terms, it demonstates that: **the growth in unit total cost of production is the composite result of twelve economic variables — the productivity growth in the four broadly defined inputs; the growth in the prices paid to acquire the services of these four inputs, and the relative importance of the cost of each input type to the total cost of all inputs.**

Thus, an industry can control or improve its unit total cost growth performance only if certain conditions are satisfied:

(1) either the productivity growth derived from each broadly defined input — capital, labor, energy, and materials — equals or exceeds the growth in the price paid for each input; or

(2) the cost-share weighted sum of the productivity growth derived from the inputs (total-input productivity growth) equals or exceeds the cost-share weighted sum of the growth in the prices paid for the inputs (total-input price growth).

In summary, productivity growth in isolation is only part of the competitiveness story. The more complete story requires a balance between input productivity growth and input price growth.

2/ The actual method used in this study to calculate the growth rates and cost shares for formula (2) are described in footnote 3 below. Note, however, that, while different in appearance, the total-input productivity growth, derived from formula (2) and the measurement conventions of footnote 6, is formally equivalent to measures derived from the more conventional total factor productivity formulas found in BLS and other economic publications and studies.

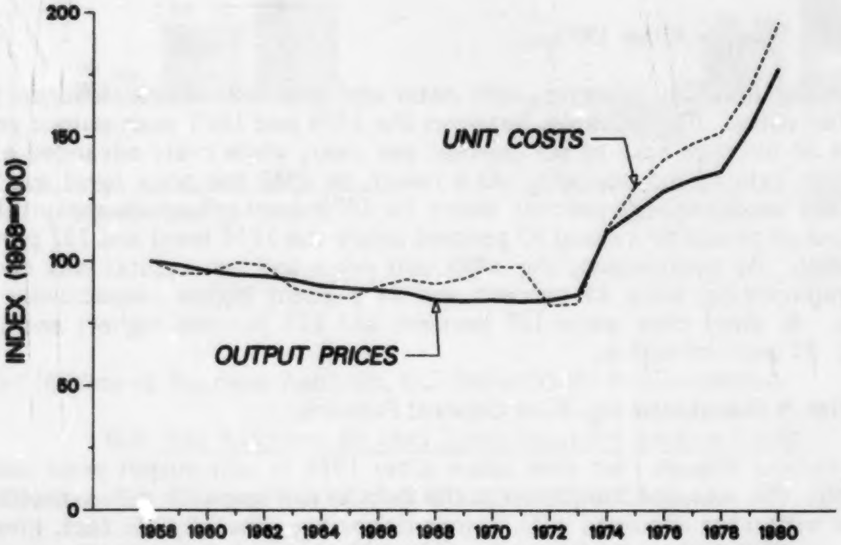
B. PRODUCTION EFFICIENCY AND THE ANATOMY OF PRODUCTION COSTS

Figures 46 through 60 summarize the economic history (1958-80) of the U.S. plastics and synthetic materials industry (SIC 282) in terms of real production, output prices, non-capital unit total costs of production 3/, input productivity, input prices, unit input costs, and the after-tax net rate of return on capital. As we proceed through this overview, it will become clear why SIC 282 is historically one of the outstanding performers among U.S. manufacturing industries.

B.1 Unit Output Prices, Costs, and Profits

FIGURE 46

Output Prices And Non-Capital Unit Total Costs, 1958-80



SOURCE: Office of Business Analysis, U.S. Department of Commerce.

Figure 46 demonstrates the historical relationship between output prices and non-capital unit total costs of production in SIC 282. This, coupled with the output price and unit total cost growth rates shown in Figure 47 illustrates the extent to which price growth is driven over time by the growth in unit production costs.

3/ As of this writing, unit price of capital and unit cost of capital measures were not yet available (However the price of capital and its several components were discussed in PART II:Section E.3, Table 27, footnote b). Accordingly, total unit costs of production in Figures 46 and 47 were computed ex-capital. However, the sum of labor, energy, and materials costs accounts for between 83 and 87 percent of the value of production. Also, note that the cost shares required in formula (2) were calulated as the simple average of the cost shares in years 1 and 2.

Unit Prices and Costs Decline 1958 To 1973...

Figure 46 shows that the unit output price index (1958=100) declined in eleven out of the twelve years between 1958 and 1971. The only exception was 1970. As a result, the output price index in 1971 was almost 16 percent below its 1958 level. During the next two years, output prices rose modestly; but the price level in 1973 was still more than 15 percent below its 1958 level. This compares to 7.5 percent higher prices for manufacturing industries overall. Non-capital unit total cost also declined -- almost 17 percent -- between 1958 and 1973.

Expressed in terms of average annual rates over peak-to-peak intervals, we find that prices declined at an average rate of 1.5 percent during 1959-66 and grew at an average rate of 3.4 percent during 1966-74. Similarly, unit cost declined at an average rate of 0.6 percent during the first interval and grew at an average rate of 3.8 percent during the second interval. 4/

...But Escalate Sharply After 1973...

Beginning in 1974, however, unit costs and unit output prices began to grow at sharply higher rates. For example, between the 1974 and 1979 peak output years, prices advanced at an average rate of 6.7 percent per year, while costs advanced at the much higher average rate of 8.5 percent. As a result, by 1980 the price level was 78 percent above its 1958 level and 105 percent above its 1973 level. Excluding capital costs, the 1980 unit cost of production stood 95 percent above the 1958 level and 137 percent above the 1973 level. By comparison, the 1980 unit price and non-capital unit cost levels in overall manufacturing were 89 percent and 84 percent higher respectively than their 1973 levels. In steel they were 127 percent and 128 percent higher; and in autos 80 percent and 92 percent higher.

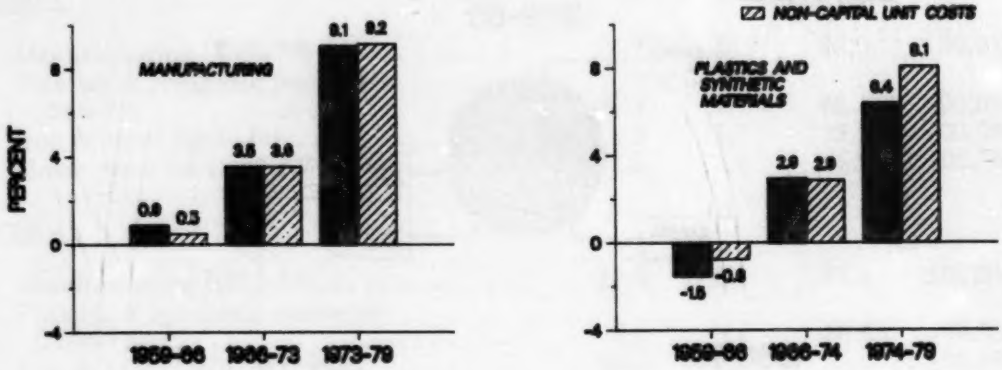
...In Line With A Manufacturing-Wide General Pattern.

The radical change that took place after 1974 in unit output price and unit cost growth in SIC 282 was not unique. On the contrary, Figure 47 shows that it was very much in line with what occurred in U. S. manufacturing generally. In fact, given that SIC 282 is such a heavy consumer of energy related inputs -- both as an energy source and a materials input (see PART II: Section D) -- its unit price and cost growth performance since 1974 compares very well with the performance of other manufacturing industries.

4/The reader may notice that the percentage change measures, presented here in PART III, differ in some cases from those presented elsewhere in this report. This is because the method of calculation used here is different from the traditional calculation: $((X_2-X_1)/X_1)x100$. The calculation used here was: $(X_2-X_1) / {}^1\!/\!_2(X_1+X_2)x100$. This change was necessitated by the need to accommodate large changes in the variables included in the unit cost-growth accounting decomposition formula (2), which holds exactly only for small changes in the variables around their initial values. In order that meaningful comparisons could be made between and among other percentage change values in PART III, all were computed by the same method.

FIGURE 47

Inter-Industry Comparison Of The Growth In Unit Output Prices And Noncapital Unit Costs Over Comparable Peak-To-Peak Intervals (Average Annual Percent Changes)



SOURCE: Office of Business Analysis, U.S Department of Commerce.

B.2 The Anatomy Of Unit Total-Input Production Costs

Revenue Shares: The Composition of Unit Price and Unit Cost...

Figure 48 describes how a dollar of revenue earned by SIC 282 was distributed in terms of average payments made to the four factors of production over major peak-to-peak intervals. 5/ While sales revenue and production costs are not necessarily the same, we will, at various places in the discussion below, also treat these distributions as reasonable approximations to the comparable distributions of total costs.

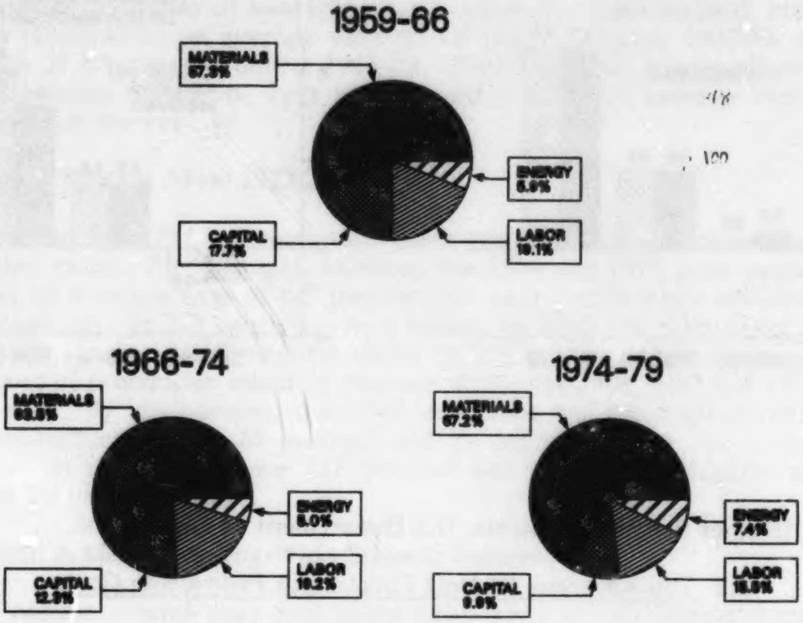
We see from Figure 48 that materials cost (including energy feedstocks) consumed on average more than 57 percent of each sales dollar earned during 1959-66; but more than 67 percent during 1974-79. While labor is the next biggest source of cost, it consumed on average only about 19 percent of each revenue dollar between 1959 and 1974; and only 15.5 percent between 1974 and 1979. Direct energy costs, meanwhile, consumed less than 6 percent of each dollar between 1959 and 1974, but its share jumped to 7.4 percent afterwards.

5/ The input revenue shares shown in Figure 48 were computed as payments to capital, labor, energy, and materials relative to the current-dollar value of gross output producted by SIC 282. The payments to capital were computed as a residual — current dollar output less payments to labor, energy, and materials.

Finally, Figure 48 demonstrates that, as a result of unit costs increasing faster than prices since 1966, the average share of revenue accurring to capital decreased by almost 45 percent between the 1959-66 and 1974-79 intervals. Capital's average revenue share was 17.7 percent during 1959-66, dropped to 12.3 percent in 1966-74, and to only 9.9 percent in 1974-79. 6/

FIGURE 48

Revenue Shares: Payments To Inputs As A Percent Of Current-Dollar Value Of Production: Peak-To-Peak Interval Percent Averages



SOURCE: Office of Business Analysis, U.S. Department of Commerce.

Sources Of Growth In Unit Production Costs...

The discussion of formula (2) in the previous section demonstrated that the growth in unit total cost of production could be traced directly to the growth in the unit cost associated with each of the four input classes -- capital, labor, energy, and materials. Here we apply a reduced version of formula (2) in order to trace the sources of the average annual peak-to-peak growth in non-capital unit total costs back to the contribution made by the average annual growth in unit labor costs, unit direct energy costs, and unit materials costs.

6/ A note of caution concerning capital's value share is in order. Since capital's revenue share was computed as a residual, it includes several categories of expense account which are traditionally not recognized as capital income, e.g., real estate taxes, sales taxes, excise taxes, etc.

TABLE 28

Inter-Industry Comparison Of Sources Of Growth In Unit Costs Of Production Over Comparable Peak-To-Peak Intervals Since 1966

	Average Percentage Contribution to Growth in Non-Capital Unit Costs			
	Labor	Energy	Materials	Total
Interval 1				
Manufacturing (1966-73)	4.7	-0.7	96.0	100.0%
Plastics & synthetic materials (1966-74)	22.3	9.5	68.2	100.0%
Iron & Steel (1966-74)	26.3	18.2	55.5	100.0%
Motor vehicles (1965-73)	51.0	2.1	46.9	100.0%
Interval 2				
Manufacturing (1973-79)	22.8	6.1	71.1	100.0%
Plastics & synthetic materials (1974-79)	7.6	3.8	88.6	100.0%
Iron & Steel (1974-79)	31.6	17.4	51.0	100.0%
Motor vehicles (1975-78)	17.1	1.7	81.2	100.0%

SOURCE: Office of Business Analysis, U.S. Department of Commerce.

Peak-to-Peak Growth In Unit Total Costs Traced To Growth In Unit Materials And Unit Labor Costs, 1966-74; But To Growth In Unit Materials Costs, 1974-79.

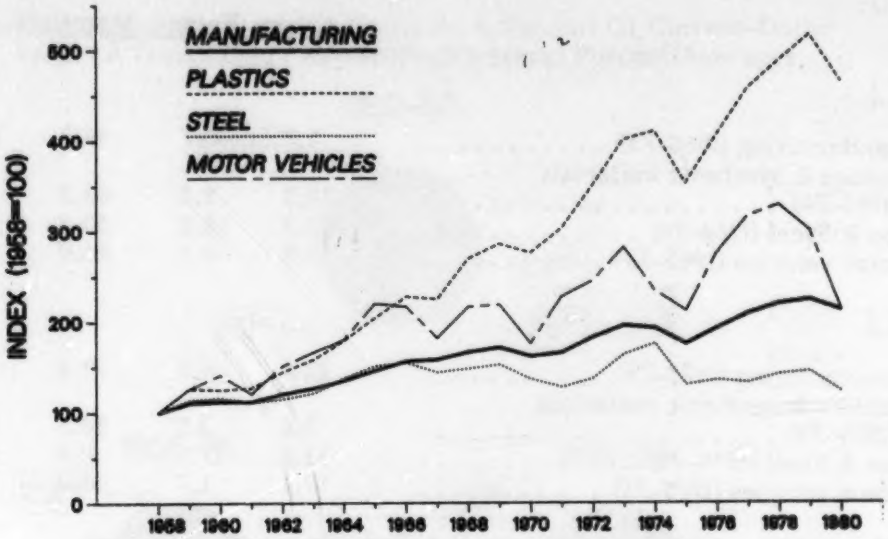
Table 28 summarizes the results of this exercise for the plastics industry and also compares the sources of growth in its non-capital unit total cost to those of overall manufacturing and to steel and autos during comparable peak-to-peak intervals. The following points are worth noting. First, more than 68.0 percent of the 1966-74 average annual increase in plastics' non-capital unit total cost was due to the growth in unit materials costs, while more than 22.0 percent was due to the growth in unit labor costs.Second, more than 88 percent of the 1974-79 average annual increase in non-capital unit cost was accounted for by the growth in unit materials costs, while the growth in unit labor costs accounted for just 7.6 percent. Third, compared either to their 1974-79 relative shares in SIC 282's total cost of production (Figure 48) or to the sources of post-1973 unit total cost growth in other manufacturing industries (Table 28), the contribution from unit materials cost in SIC 282 is inordinately large, while the contribution from unit labor costs is inordinately small.

To learn more about the determinants of the plastic industry's historical unit price and non-capital cost patterns, we turn now to an examination of the history of the three rate of growth measures -- input prices, input productivity, and unit input costs -- related to the three broad non-capital input classes -- labor, energy, and materials -- delineated in formula (2) above. We also examine the history of capital productivity and the rate of return to capital. The historical information needed both to conduct this examination and to compare the productive efficiency of plastics with other selected U.S. manufacturing industries -- total manufacturing, iron and steel, and motor vehicles and equipment -- is found in the figures and tables which follow.

B.3 Output Growth And Productivity Growth

FIGURE 49

Inter-Industry Comparison Of Constant-Dollar Output, 1958-80



SOURCE: Office of Business Analysis, U.S.Department of Commerce.

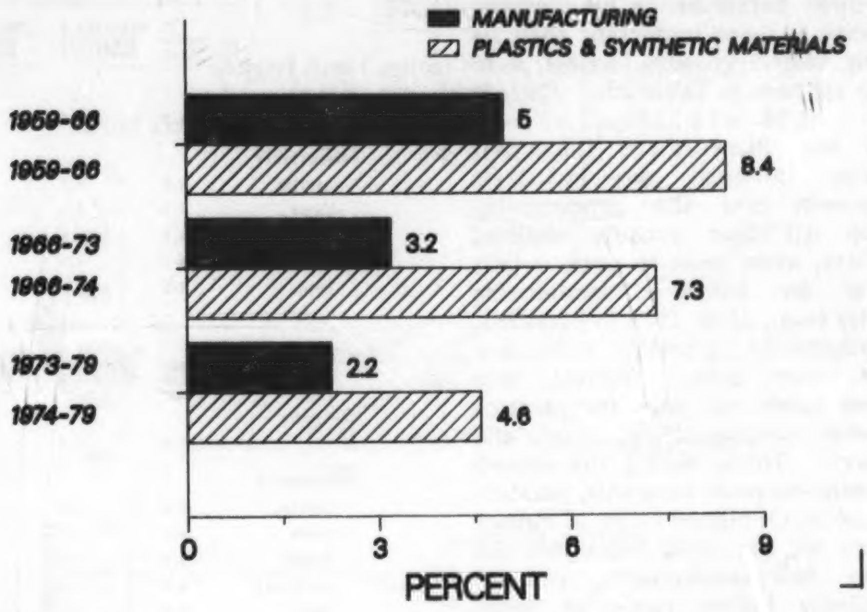
A Growth Industry...

Over the entire 1958-80 interval, real output peaked at successively higher levels in 1959, 1966, 1969, 1974 and 1979 (Figure 49). Between the 1959 and 1979 output peaks, the level of real output (constant 1972 $) more than quadrupled -- from $3,534.4 million in 1959 to $11,443.3 million in 1974. This growth record is outstanding among U.S. industries. For example, total manufacturing real output increased only 124 percent between the 1959 and 1979 peaks, while the real output of the steel industry increased only 25.3 percent between its 1960 and 1979 peaks. Another high flier, during the 1958-80 interval, was the auto industry. However, its output grew 132.6 percent between its 1960 and 1978 output peaks -- only about one-third as fast as the 308.6 percent peak-to-peak increase recorded by plastics.

Presented in terms of average annual rates of growth over comparable peak-to-peak intervals, Figure 50 shows that real output in plastics grew as follows: 8.4 percent in 1959-66; 7.3 percent in 1966-74; and 4.6 percent in 1974-79. This compares to peak-to-peak rates of 5.0, 3.2, and 2.3 percent for total manufacturing.

FIGURE 50

Inter-Industry Comparison Of Rates Of Growth In Constant-Dollar Gross Output Over Comparable Peak-To-Peak Intervals (Average Annual Percent Changes)



SOURCE: Office of Business Analysis, U.S. Department of Commerce.

High Output Growth Is A Major Determinant Of Plastics' High Productivity Growth; And...

Among the factors which contributed to the superior 1958-80 output growth performance by plastics, perhaps none is more important than its outstanding output growth. Evidence to this effect appears in Table 29.

We see there three important relationships between an industry's output growth and the productivity growth of it's four broadly defined inputs. First, when peak-to-peak output growth in an industry decelerates significantly (e.g., after 1974 in plastics), input productivity growth, with few exceptions, does also. Second, this phenomenon holds not only for plastics but for total manufacturing, steel, and autos as well. Third, during the second and third peak-to-peak intervals, plastics not only had much higher rates of output growth then did the other industries but also, with few exceptions, it had correspondingly higher rates of input productivity growth. Particularly noteworthy is the outstanding efficiency improvements achieved by plastics in its use of labor and energy inputs. Ominously, however, the industry was not particularly successful in improving the efficiency of its most important input — materials.

...Average Total-Input Productivity Growth Is More Than Double The All-Manufacturing Rate After 1966.

Finally, Table 29 shows that between 1959 and 1966, average total-input productivity growth in plastics was 0.5 percentage points better than the comparable peak-to-peak all-manufacturing rate — 1.7 versus 1.2 percent. Between 1966 and 1974, however, total-input productivity growth in plastics was more than 1.7 percentage points greater than that in all-manufacturing — 2.7 versus 1.0 percent. During 1974-79, average total-input productivity growth in plastics fell to one-half its 1966-74 rate

TABLE 29

RELATIONSHIP BETWEEN INPUT PRODUCTIVITY AND REAL OUTPUT GROWTH IN COMPARABLE PEAK-TO-PEAK INTERVALS (AVERAGE OF ANNUAL PERCENT CHANGES)

	ALL MANU-FACTURING	PLASTICS & SYNTHETIC MATERIALS	PRIMARY IRON & STEEL	MOTOR VEHICLES & EQUIPMENT
INTERVAL 1				
CONSTANT-DOLLAR OUTPUT	5.0	8.4	4.4	8.6
INPUT PRODUCTIVITY				
CAPITAL	2.0	1.5	2.9	6.5
LABOR	3.1	3.5	3.1	4.3
ENERGY	1.2	1.0	0.7	4.0
MATERIALS	0.1	1.3	1.0	1.1
TOTAL	1.2	1.7	1.8	2.1
INTERVAL 2				
CONSTANT-DOLLAR OUTPUT	3.2	7.3	1.6	3.1
INPUT PRODUCTIVITY				
CAPITAL	-0.8	3.0	1.4	1.8
LABOR	2.7	6.2	2.1	2.2
ENERGY	0.9	2.6	1.1	1.7
MATERIALS	0.7	1.6	-1.9	1.4
TOTAL	1.0	2.7	-0.1	1.7
INTERVAL 3				
CONSTANT-DOLLAR OUTPUT	2.3	4.6	-3.8	3.0
INPUT PRODUCTIVITY				
CAPITAL	-1.0	1.6	-2.1	1.7
LABOR	1.5	5.8	-1.5	2.3
ENERGY	1.8	6.3	-2.2	1.7
MATERIALS	0.8	0.1	0.3	-0.8
TOTAL	0.6	1.3	-0.8	0.1

PEAK-TO-PEAK intervals are defined as follows:

	Interval 1	Interval 2	Interval 3
MANUFACTURING	1959-66	1966-73	1973-79
PLASTICS	1959-66	1966-74	1974-79
IRON & STEEL	1959-66	1966-74	1974-79
MOTOR VEHICLES	1960-65	1965-73	1973-78

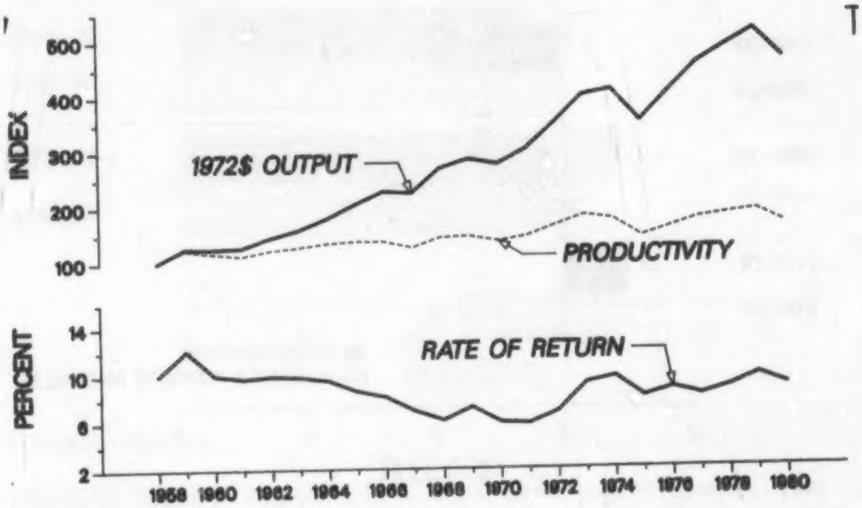
SOURCE: Office of Business Analysis, U.S. Department of Commerce.

-- 1.3 versus 2.7 percent -- but it still was 0.7 percentage points better than the all-manufacturing rate -- 1.3 verses 0.6 percent.

B.4 Capital Productivity And The After-Tax Rate Of Return To Capital

FIGURE 51

Output And Capital Productivity Levels
(Index, 1958=100),
And The After-Tax Rate Of Return On Capital, 1958-80 a/



a/ Capital income includes interest expense.

SOURCE: Office of Business Analysis, U.S. Department of Commerce.

Figure 51 describes the historical profiles of capital productivity and the after-tax rate of return to capital. It also demonstrates that the profiles of both are strongly influenced by movements in real output. The similarity in both cyclical pattern and trend across the three series is obvious. For example, the level of capital productivity was higher at each successive output peak -- 1959, 1966, 1974, and 1979. Relative to 1958, capital was almost 90 percent more productive in 1979.

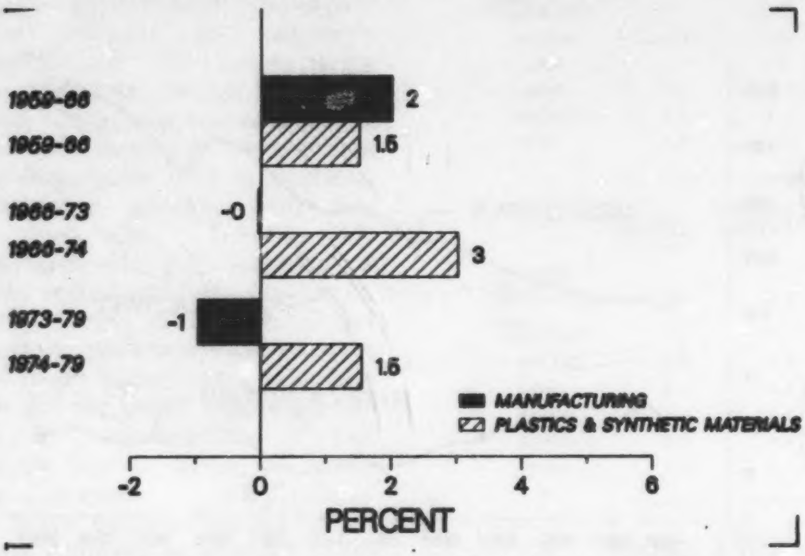
Below Average Capital Productivity Growth 1959-66 Due To High Rates Of Capital Formation; But...

On a peak-to-peak basis, capital productivity advanced at an average annual rate of 1.5 percent per year between the 1959 and 1966 output peaks. Figure 52 shows that this performance was one-half a percentage point less than that of all-manufacturing. However, Figure 52 does not show that the industry was adding to its real stock of plant and equipment at a rate substantially in excess of other manufacturing industries; with its output growing at more than 8.0 percent per annum, the industry doubled its stock of real net plant and equipment between 1958 and 1969. By contrast, the real net capital stocks of all-manufacturing increased by just 40 percent.

Since 1970, the rate of net plant and equipment growth has settled into a pattern more in line with other manufacturing industries. For example, during 1970-75 and 1975-80, the net capital stock of SIC 282 grew at average annual rate of 4.0 and 2.8 percent respectively, while that of total manufacturing grew at rates of 2.6 and 3.3 percent.

FIGURE 52

Comparison Of Capital Productivity Growth Over
Comparable Peak-To-Peak Intervals



SOURCE: Office of Business Analysis, U.S. Department of Commerce.

...Capital Productivity In SIC 282 Runs Ahead Of Other Manufacturing Industries 1966-80.

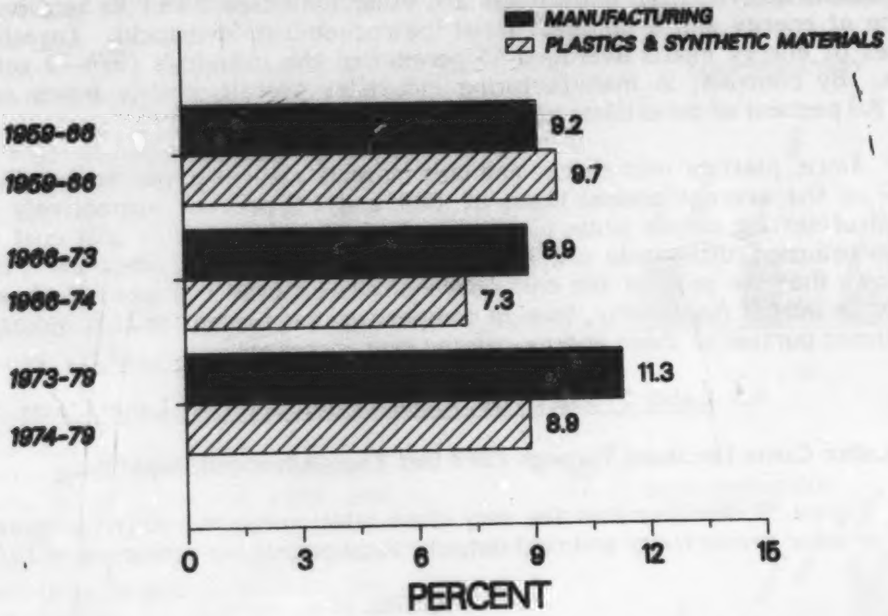
Compared with the 1959-66 interval, the average annual rate of capital productivity growth doubled to 3.0 percent between the 1966 and 1974 output peaks. But, following the 1973 energy crisis, average 1974-79 productivity growth declined by almost one-half, to 1.6 percent. Nevertheless, Figure 52 shows that both these rates compare quite favorably with what occurred in other manufacturing industries during comparable peak-to-peak intervals. For example, average annual capital productivity growth in overall manufacturing actually turned negative during its 1973-79 peak-to-peak interval.

After 1966, The Average Rate Of Return Falls Below The All-Manufacturing Rate...

Figure 53 compares plastics' after-tax rate of return on fixed capital (plant, equipment, land, natural resources), excluding depreciation, to the return earned by other manufacturing industries. We see there that the 9.1 percent average rate of return made by plastics during the 1959-66 interval was in line with the 9.2 percent rate earned by manufacturing industries overall. But, during the 1966-74 interval, the industry's average rate of return was only 7.3 percent — well below the all-manufacturing 8.9 percent rate during 1966-73. One would not expect this result in view of the industry's excellent relative record in controlling costs through 1974.

FIGURE 53

Inter-Industry Comparison Of Average After-Tax
Rates Of Return On Gross Book Value Of Capital Stock
Over Comparable Peak-To-Peak Intervals a/



a/ Includes interest expense.

SOURCE: Office of Business Analysis, U.S. Department of Commerce.

...As Price Increases Don't Match Cost Increases; Suggesting Strong Competition...

One explanation for this anomaly is found back in Figure 46 which shows an interesting pattern between the unit price and non-capital unit cost series. The latter grows faster than unit prices during periods of business cycle activity -- 1960-61 and 1966-71. As a result, between 1967 and 1971 the industry generally did not increase its prices in tandem with increases in its unit-production costs. Apparently, competitive pressures were sufficient to cause the industry to absorb a bigger portion of cyclical cost increases than was the case for manufacturing industries in general.

...And Environmental Expenses Mount...

Another contributing factor was the relatively heavy burden imposed on the industry by federal pollution control regulations which began in 1967. From 1967 to 1974, the industry's real net stocks of pollution control capital grew more than 1200 percent -- from \$39.4 million to \$450.5 million (1972\$). Coupling both these facts with the industry's above average rate of growth in capital through the late sixties, rationalizes plastics' less than average rate of return between its 1966 and 1974 output peaks.

...Then Energy Prices Kick In.

Its below average rate of return (8.9 vs. 11.3 percent) in the 1974-79 interval can be similarly explained. Except, the explanation must now include the very uneven impact of the post-1973 escalation in energy prices. Plastics is an inordinately heavy consumer of products derived from natural gas and other fuels (see PART II: Section D), both as a source of energy and a material input (petrochemical feedstock). Together, these two classes of energy inputs averaged 45 percent of the industry's 1974-79 total production costs. By contrast, in manufacturing industries overall, energy inputs constitute less than 3.0 percent of total costs of production.

Since plastics' unit energy and unit materials prices advanced rapidly during 1974-79 — at the average annual rates of 13.4 and 8.9 percent respectively — one might expect offsetting output price increases. In fact, prior to 1974 unit cost of production always returned ultimately to the growth path of unit prices. Since 1974, though, Figure 46 shows that the path of the unit cost index has stayed consistently above that of the unit price index. Apparently, foreign competition has forced the U.S. industry to eat a significant portion of these energy-related cost increases.

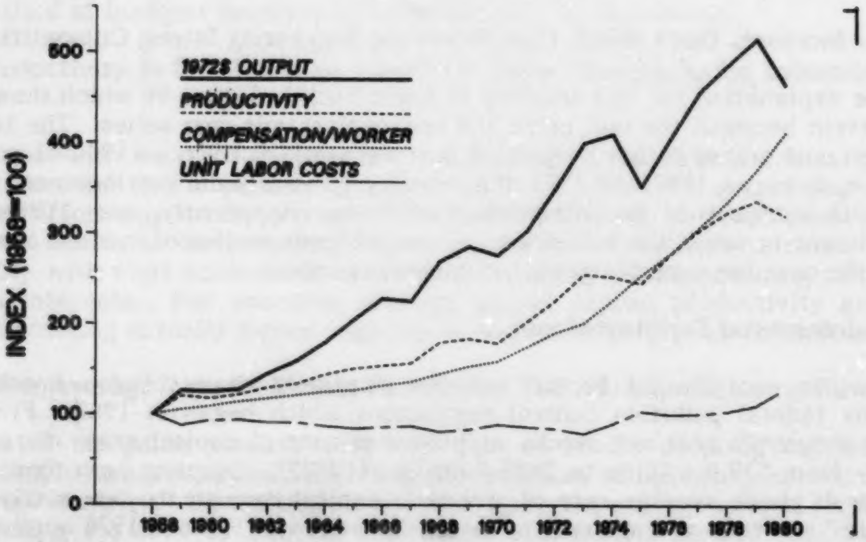
B.5 Labor Productivity, Labor Prices, and Unit Labor Costs

Unit Labor Costs Declined Through 1973 But Then Advanced Rapidly...

Figure 54 demonstrates the very close relationship that exists between the growth paths of labor productivity and real output. Real output per employee in 1974

FIGURE 54

Output, Labor Productivity, Labor Prices, And Unit Labor Costs, 1958-80



SOURCE: Office of Business Analysis, U.S. Department of Commerce.

was 2.5 times the level in 1958, and the 1979 level was 3.4 times the 1958 level. Figure 54 also shows that, except for a slight, cycle-induced rise during 1969-70, unit labor costs declined continuously between 1959 and 1973 -- the 1973 level was 79 percent of its 1958 level. However, since 1973 unit labor costs have increased substantially -- with big jumps coming in the 1974-75 period and in the 1979-80 period. By 1980, unit labor costs were 28 percent above their 1958 level and 63 percent above their 1973 level.

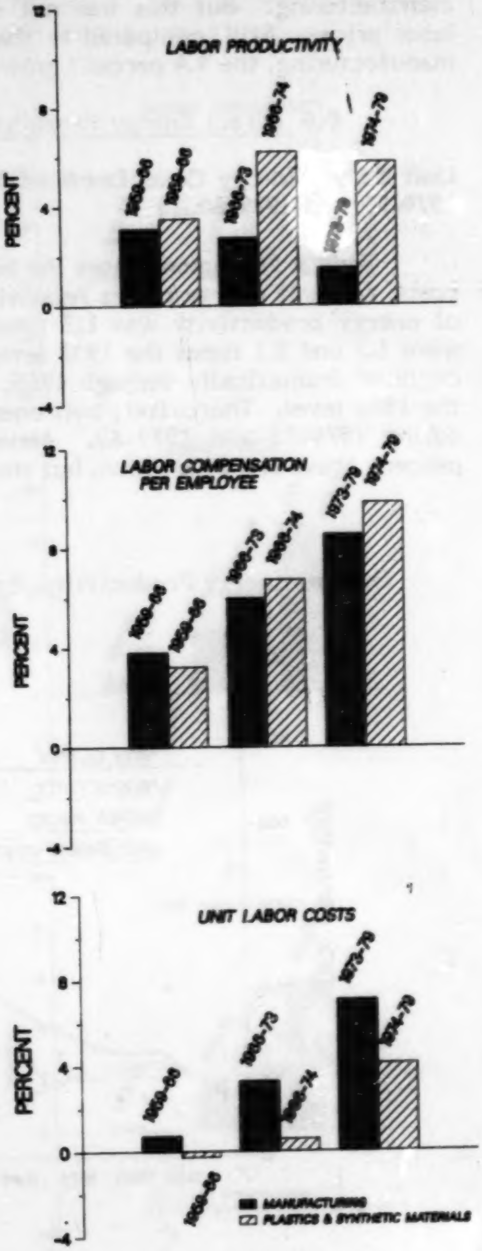
As Outstanding Labor Productivity Growth Largely Offsets Growth In Labor Prices Through 1965...

Figure 55 (bottom panel) shows that unit labor costs in plastics declined at an average rate of 0.3 percent between the peak years of 1959 and 1966. During this time, labor productivity growth (top panel) exceeded labor price growth (middle panel), with the two measures averaging 3.5 and 3.2 percent per year respectively.

Over the next peak-to-peak interval, 1966-74, unit labor costs advanced very slowly, at an average annual rate of only 0.6 percent. Sharp advances in labor productivity of 6.2 percent during this period nearly offset the 6.7 percent average rate of growth in labor prices. The bottom panel of of Figure 55 demonstrates that the performance of plastics with respect to keeping unit labor costs in balance during this period was markedly superior to the performances of manufacturing industries generally. The top two panels of Figure 55 further demonstrate that this outcome was produced by plastics' extraordinary labor productivity growth; not because its labor prices were advancing at significantly slower rates.

FIGURE 55

Labor Input Comparison Over Comparable Peak-To-Peak Intervals (Average Annual Percent Changes)



SOURCE: Office of Business Analysis, U.S. Department of Commerce.

...But Labor Prices Grow Faster Than Labor Productivity Since 1974.

Over the last peak-to-peak interval, 1974-79, unit labor cost growth broke sharply from its earlier historical pattern and advanced at an average rate of 4.1 percent. The reason, however, is not to be found in a decline in labor productivity growth. It still advanced at a 5.8 percent average rate — several times the average rate recorded by all-manufacturing. But this was not enough to offset the 9.9 percent average growth in labor prices. Still, compared to the unit labor cost growth rates of 7.1 percent in total manufacturing, the 4.4 percent growth in SIC 282 shines.

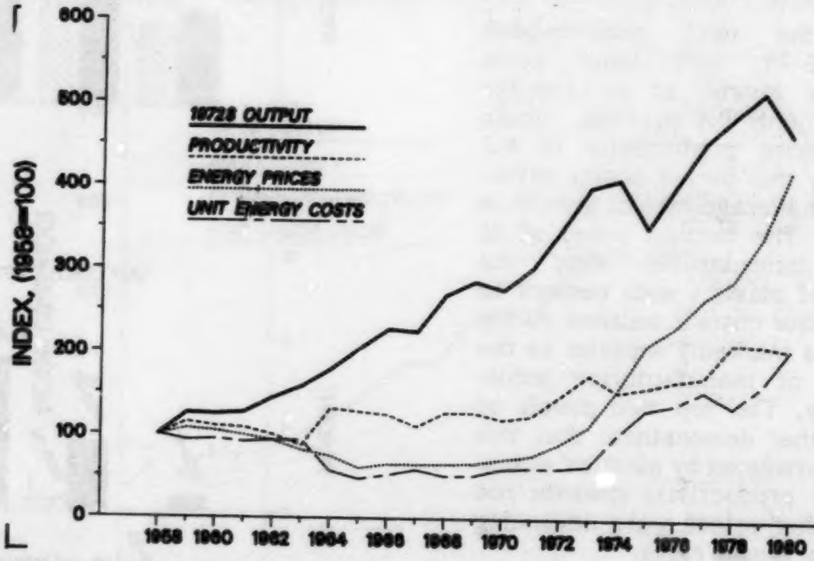
B.6 Direct Energy Productivity, Energy Prices, And Unit Energy Costs

Unit Direct Energy Costs Declined Through 1969, But Then Advanced, With Big Jumps In 1974-75 And 1979-80...

Figure 56 demonstrates the historical profiles of energy productivity, unit energy costs, and unit energy prices relative to the growth path of real output. The 1966 index of energy productivity was 1.3 times the 1958 level, while the 1973 and 1979 indexes were 1.7 and 2.1 times the 1958 level, respectively. Meanwhile, unit direct energy costs declined dramatically through 1969, with costs in the latter year at only 52 percent of the 1958 level. Thereafter, unit energy costs rose persistently, with big jumps occurring during 1974-75 and 1979-80. Nevertheless, the 1974 unit cost index stood just 2.0 percent above the 1958 value, but the 1980 index was more than twice that in 1958.

FIGURE 56

Output, Energy Productivity, Energy Prices, And Unit Energy Cost, 1958-80 a/



a/ Energy here is only direct energy used for heat, power, and transportation. Energy inputs used as feedstocks are included in materials.

SOURCE: Office of Business Analysis, U.S. Department of Commerce.

...As Energy Prices Declined 1958-66...

Figure 57 (bottom panel) shows that unit direct energy costs actually declined at an average rate of 8.1 percent in 1959-66--the result largely of an 7.1 percent average rate of decline in energy prices (middle panel). Energy productivity, during this period, grew at an average rate of only 1.0 percent (top panel).

...But Soared 1972-75...

The downward trend of energy prices completely reversed itself in 1966-74. Unit energy costs grew at an average rate of 8.2 percent. Average energy productivity growth accelerated to 2.6 percent but this was not near enough to offset the 10.9 percent average growth in energy prices, which grew at rates of 18.1, 20.4, and 33.3 percent in 1972, 1973, and 1974 respectively.

...And Again In 1979-80: Offsetting Dramatic Improvements in Direct Energy Efficiency.

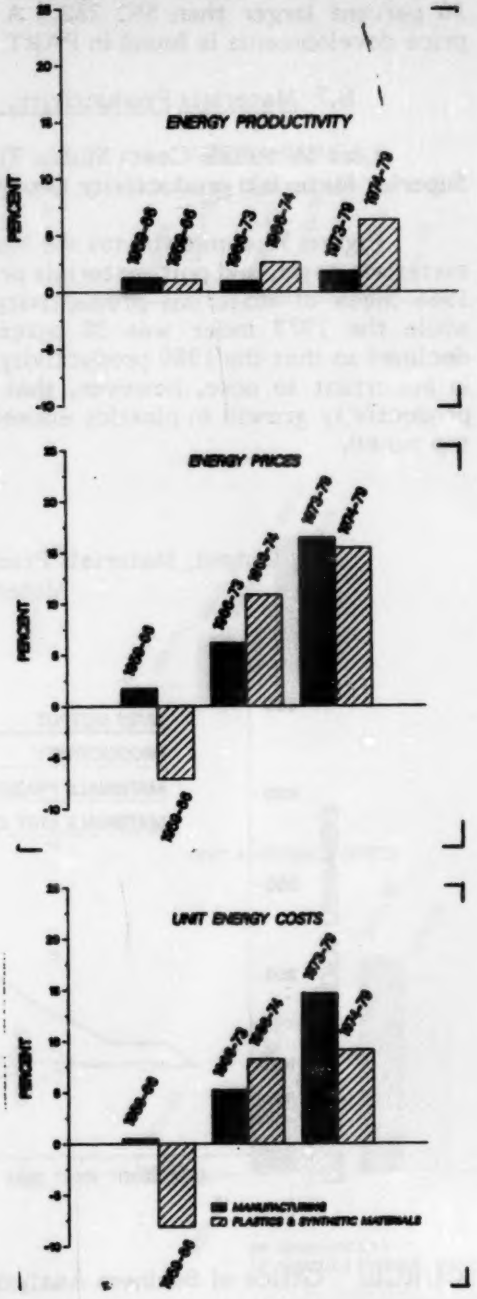
Unit direct energy costs continued to grow in excess of 9.0 percent per year through 1974-79; despite the fact that average annual energy productivity growth increased to 6.3 percent -- more than double its 1966-74 average rate. The reason: energy prices grew at a 15.5 percent average annual rate. Compared to other manufacturing industries, though, Figure 57 demonstrates that the industry's progress in improving energy efficiency was not only well above that of other industries but also, as a result, its growth in unit energy cost was well below.

Direct Energy Costs Are A Relatively Large Proportion of Total Costs...

Compared with overall manufacturing, plastics is an energy intensive industry. Its direct energy value share averaged between 5 and 6 percent during 1959-74, but jumped to an average of 7.4 percent during 1974-79; as a result of

FIGURE 57

Direct Energy Input Comparisons Over Comparable Peak-To-Peak Intervals (Average Annual Percent Changes)



SOURCE: Office of Business Analysis, U.S. Department of Commerce.

the continuous escalation in energy prices after 1973 (Figure 56). In contrast, the all-manufacturing energy value share averaged just 2.2 percent between its 1959 and 1973 output peaks and just 3.2 percent between its 1973 and 1979 peaks.

Plastics and synthetic materials is also more energy intensive than motor vehicles, but it is not in the same category with steel, which has a direct energy cost share 40 to 50 percent larger than SIC 282. A more detailed discussion of direct energy use and price developments is found in PART II: Section D.

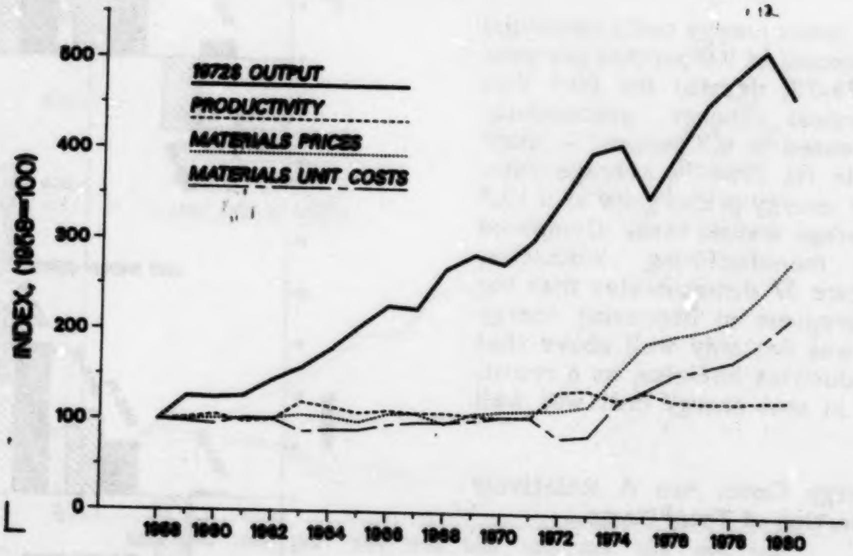
B.7 Materials Productivity, Materials Prices, And Unit Materials Costs

Unit Materials Costs Stable Through 1973 But Inflate Sharply Thereafter; Despite Superior Materials productivity Growth...

Figure 58 demonstrates the historical profiles of materials input productivity, unit materials costs, and unit materials prices relative to the growth path of real output. The 1966 index of materials productivity was only 12 percent higher than its 1958 value, while the 1973 index was 38 percent higher. Thereafter, the level of productivity declined so that the 1980 productivity index was only 28 percent above the 1958 value. It is important to note, however, that throughout the entire 1958-80 interval, materials productivity growth in plastics exceed that of most manufacturing industries (Figure 59, top panel).

FIGURE 58

Output, Materials Productivity, Materials Prices, And Unit Materials Costs, 1958-80



SOURCE: Office of Business Analysis, U.S. Department of Commerce.

Unit materials cost declined slightly between 1958 and 1966, followed between 1967 and 1971 by a small cycle-induced increase in unit materials costs. But, in the aftermath of the 1973 energy crisis, unit material costs escalated rapidly. The 1974 unit cost index stood 24 percent above the 1958 value, while the 1980 index stood 120 percent above it. The reason: more than 55.0 percent of the materials inputs of the industry are either raw or refined petrochemical feedstocks (see PART II: Section D).

...As Productivity Growth Completely Offsets Price Growth During 1959-66.

Figure 59 (bottom panel) shows that, during the 1959-66 peak-to-peak interval, unit materials costs actually had a negative average annual rate of growth (-0.2 percent) because productivity in the use of materials grew at an average annual rate of 1.3 percent, while the unit price of materials inputs grew at only a 1.1 percent average rate. Figure 59 shows that similar results occurred in overall manufacturing.

Except for 1974, The Same Was True During 1966-74; But...

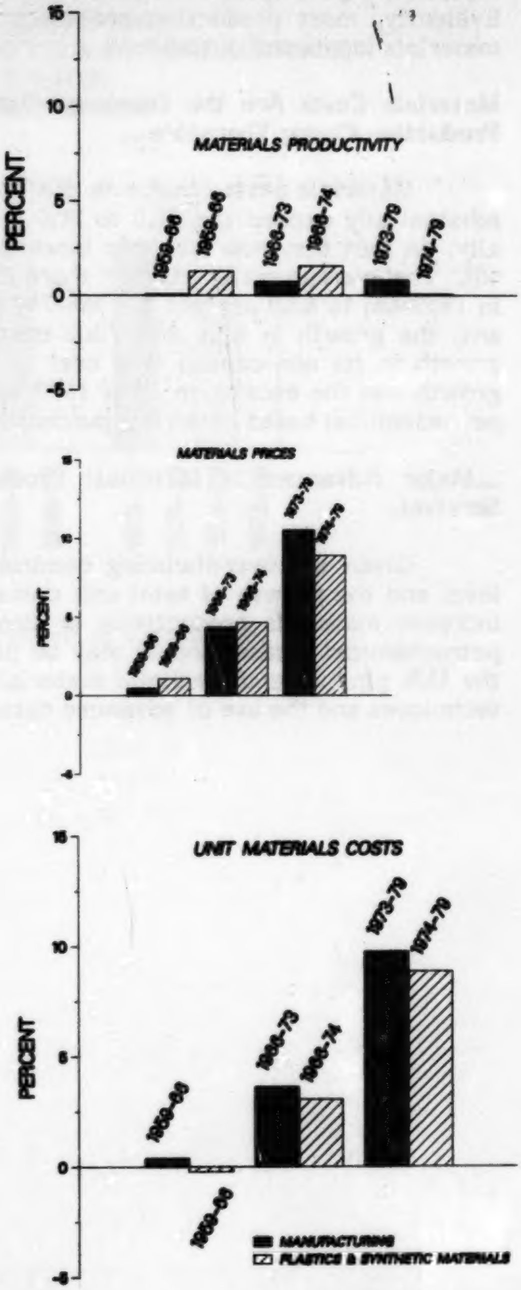
During the 1966-74 interval, unit materials cost moved forward at an average annual rate of 3.1 percent. But, most of that is explained by the 26.9 percent jump in prices in 1974 — a reflection of the post-1973 escalation in natural gas feedstock prices to the industry. Thus, average materials price growth of 4.6 percent per year overwhelmed the 1.6 percent per year average growth in materials productivity.

...Uninterrupted Near Double-Digit Price Advances And Flat Productivity Send Unit Materials Costs Soaring After 1974.

Pushed by rapidly rising prices for petrochemical feedstocks and other petrochemical-based materials inputs bought from other chemical industries,

FIGURE 59

Materials Input Comparison Over Comparable Peak-To-Peak Intervals (Average Annual Percent Changes)



SOURCE: Office of Business Analysis, U.S. Department of Commerce.

unit materials costs continued to escalate in the 1974-79 interval, but at more than twice the 1966-74 average rate. The 8.9 percent average rate of increase was the result of an 8.9 percent average rate of price increase and an anemic 0.1 percent averate rate of materials productivity growth. Figure 59 (middle panel) shows that similar growth in materials prices occurred in other manufacturing industries since 1973. Moreover, Figure 59 (top panel) demonstrates that the lack of significant improvement in the use of materials inputs since 1974 is a shared characteristic of U.S. manufacturing industries. Evidently, most production processes contain a strong fixed proportionality between materials inputs and output.

Materials Costs Are the Dominant Factor in both the Level and the Growth of Unit Production Costs; Therefore...

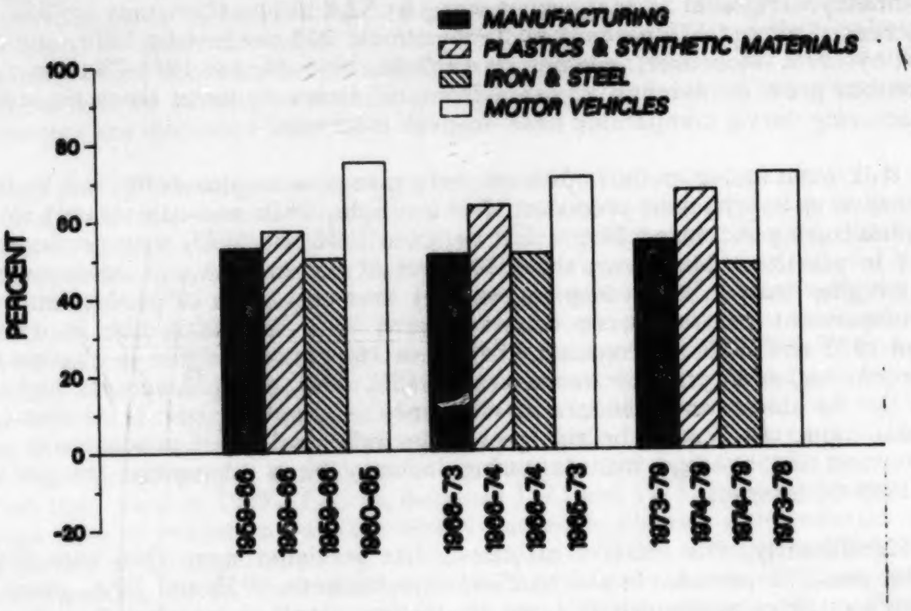
Materials costs constitute the lion's share of total production costs in plastics and substantially exceed the 51.0 to 54.0 percent shares for manufacturing industries generally. In fact they now rival the more than 70 percent cost share found in autos. (Figure 60). The average materials cost share in total value of production rose from 57.3 percent in 1959-66; to 63.5 percent in 1966-74; to 67.1 percent in 1974-79. Perhaps more important, the growth in unit materials costs accounted for more than 88.0 percent of the growth in its non-capital unit cost of production since 1974. A major source of this growth was the escalation after 1973 in the price of petrochemical feedstocks and other petrochemical based materials purchased from other chemical industries.

...Major Advances in Materials Productivity Growth May be Vital to the Industry Survival.

Given the overwhelming dominance of energy driven materials costs in both the level and the growth of total unit costs, techncial innovations which either significantly increase materials productivity or produce competitive synthetic substitutes for its petrochemical - based inputs may be particularly vital to the future competitiveness of the U.S. plastics and synthetic materials industry (see, e.g., research in biotechnological techniques and the use of advanced catalytic agents discussed in PART I: Section A).

FIGURE 60

Inter-Industry Comparison Of Materials Costs As A Percent Of Current-Dollar Gross Output Over Comparable Peak-To-Peak Intervals
(Average Annual Percent Share)



SOURCE: Office of Business Analysis, U.S. Department of Commerce.

Summary

THE U.S. PLASTICS AND SYNTHETIC MATERIALS INDUSTRY IN PERSPECTIVE

The plastics and synthetic materials industry (SIC 282) has been one of the premier growth industries of the U.S. post-war economy. In 1958, the industry was still in its infancy. It's level of real output was just $2.8 billion (Constant 1972$). However, this increased almost 128 percent by 1966; almost 250 percent by 1974; and almost 416 percent by 1979. Moreover, between its 1959-66, 1966-74, and 1974-79 output peaks, SIC 282's output grew on average at rates from 1.7 times to twice those recorded for all-manufacturing during comparable peak-to-peak intervals.

This outstanding output growth performance was also reflected in its relative performance as an efficient producer. For example, while non-capital unit total costs in all-manufacturing increased 58 percent between 1958 and 1973, they declined almost 18 percent in plastics. Moreover, the 1980 level of non-capital unit costs were only 100 percent higher than in 1958; despite the fact that unit costs of production in this very energy-dependent industry were driven upward by a dramtatic rise in energy prices between 1973 and 1980. In contrast, they were 164 percent higher in all-manufacturing, 233 percent higher in primary iron and steel (SIC 331), and 135 percent higher in autos (SIC 371). By almost any standard of efficiency — growth in unit total costs, growth in individual input unit costs, or the growth in individual input productivity — SIC 282 outperformed the average manufacturing industry by a substantial margin during the entire 1958-80 interval.

Significantly, this relative efficiency has persisted since 1966 with little change from the pre-1966 period. In the halcyon days between 1958 and 1966, most all manufacturing industries performed at rates of efficiency well above what they have achieved since, and plastics is no exception. During this time, the peak-to-peak (1959-66) average annual growth in the noncapital unit cost in manufacturing industries overall was 0.47 percent, while in plastics it was -0.74 percent. Between its 1966 and 1973 output peaks, all-manufacturing non-capital unit total costs grew at the average annual rate of 3.6 percent compared to only 2.9 percent for SIC 282 between its 1966 and 1974 output peaks. Finally, between 1973 and 1979, unit costs in all-manufacturing sprinted along at the average annual rate of 9.1 percent compared to 8.1 percent in plastics between its 1974 and 1979 output peaks.

Even more striking, however, is the fact that, since 1966, peak-to-peak capital, labor, and direct energy productivity growth rates in plastics have exceeded the comparable peak-to-peak all-manufacturing rates by a factor of 3 or more. As a result, the post-1966 peak-to-peak rates of growth in all-manufacturing unit labor costs were between 1.7 and 4.5 times greater than those found in SIC 282. Equally noteworthy is plastics' extraordinary improvement in direct energy efficiency since 1973. Direct energy productivity in plastics grew at a peak-to-peak (1974-79) average annual rate of 6.3 percent, while the all-manufacturing peak-to-peak (1973-79) rate was only 1.8 percent. As a result, all-manufacturing unit energy costs grew at the average annual rate of 14.7 percent, while the growth in plastics was only 9.2 percent. Finally, including capital, total-input productivity growth in plastics has been more than double the peak-to-peak rate record for all-manufacturing.

IS THE FUTURE AS BRIGHT AS THE PAST?

The domestic plastics and synthetic materials industry (SIC 282) has an impressive record of innovation, growth, and efficiency in the 1958-1980 period. It is outstanding, even among the "growth" industries of the post-war period. But, the industry's recent performance in several important economic measures, coupled with recent and still to be digested developments in the pricing and production of basic energy feedstocks, raises important questons about the industry's future. It has been suggested that, at best, there is considerable doubt about its future ability to compete internationaly and, at worst, the industry must now be labeled as mature and declining. 7/ Selected important examples of these factors are discussed below.

Since the 1973 energy crisis, many of the industry's economic health indicators have become much less robust. First, the 1977-79 peak-to-peak rate of growth in output demand fell to approximately one-half its pre-1974 average rate. Second, the industry's real net productive plant stock declined at the average annual rate of -0.13 percent between 1974 and 1979, compared with positive growth of 1.88 percent during 1966-74 and 6.9 percent during 1959-66. Similarly, the productive equipment stock growth declined to 4.1 percent 1974-79 versus 5.4 and 7.4 percent during 1966-74 and 1959-66 respectively. Third, the quality level of plastics' real productive plant stock fell (percent of capital stock less than 5-years old) by 1979 to only 37 percent of that registered in 1968, and the quality of its productive equipment stock fell to 75 percent of its quality level in 1968. Moreover, for both types of stocks, the 1979 quality levels were even well below what they were in 1959. Fourth, between 1973 and 1978, the positive gap between the average rate of return to common equity earned in plastics and synthetic materials and that earned in all-manufacturing closed and, in 1979-80, actually fell below the all-manufacturing rate. Fifth, the industry's 1974-79 average real rate of return on invested capital before taxes was only 66 percent of its 1959-66 average rate. Finally, the positive gap between the industry's after-tax nominal return to invested capital and its after-tax current cost of capital declined in 1974-79 relative to its average value both in 1966-74 and in 1959-66. Indeed, by 1977 the industry's current cost of capital exceeded its rate of return to capital for the first time since 1958 and it continued to exceed it each year in the 1977-80 period.

These developments appear to be the result of an interrelated set of factors, including: the 1974-75 and 1979-80 recessions which reduced output growth and returns to scale, rapidly rising energy prices which disproportionately affected costs and profits in this very energy intensive industry, general inflation and strong domestic and foreign-based competition which prevented the industry from increasing its prices at the same rate as its costs, high levels of government mandated expenditures for pollution abatement capital, and the maturation of the industry. An attempt to sort out the relative importance of each factor is beyond the scope of this study. Nevertheless, based on the industry's historical performance and input structure, it seems likely that, in the

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7/ For example, A Competitive Assessment of the U.S. Petrochemical Industry (Office of Competitive Assessment (OCA), U.S. Department of Commerce, August, 1980) describes many important problems faced by the petrochemical industry. It should be emphasized, however, that the "petrochemical industry" as defined in OCA's report is not identical to the Plastics and Synthetic Materials industry (SIC 282) covered in this report. OCA's report dealt primarily with those elements of the chemical industry that produce "commodity" petrochemical that are the feedstock inputs to SIC 282. A discussion of the OCA report follows in the text above.

short-to-intermediate future, the industry will return to its pre-energy-crisis form, during a substained period of strong output growth and declining energy prices. How the industry performs during the current expansion, which began in 1983, should provide clarifying evidence on this subject.

Another uncertainty relates to the fact that the industry's aggregate material costs are composed more than 55 percent of both petrochemical feedstocks and petrochemical-based derivatives. Aggregate materials costs have risen dramatically since 1973 — to the point where they now account for almost 70 percent of total costs of production — and the growth in unit materials costs is responsible for almost 90 percent of the growth in non-capital unit total costs of production since 1974. It is important to note, therefore, that the U.S. petrochemical industry has historically enjoyed a distinct advantage over its European and Japanese competitors. Until very recently, for example, the prices of domestic sources of its two most important energy and materials inputs — natural gas and petroleum — have been under U.S. price controls. As a result, it has enjoyed both lower price levels and lower rates of inflation for direct as well as indirect use of these inputs. This condition began to change in 1978 with the enactment of the Natural Gas Policy Act, which deregulated "new" U.S.-source gas in stages, with full deregulation in 1985. Further dilution of this advantage occurred in 1981, when the U.S. completely decontrolled U.S. oil prices. Nevertheless, unless comparable action follows on natural gas prices, it is estimated that U.S. petrochemical industry will still have the advantage that 40 to 60 percent of U.S. natural gas will still remain under some form of price control even after 1985. 8/

A final related uncertainty is the fact that the natural gas-rich countries of Canada, Mexico, and Saudia Arabia have recently developed state-of-the-art petrochemical plants, and that each of these countries have the potential to feed their nationalized petrochemical industries with captive natural gas priced well below both World and U.S. prices. However, the danger from this source will likely only materialize in the long-run because the U.S. plastics and synthetic materials industry operates sufficiently downstream in the petrochemical industry chain that it will be protected for the forseeable future by the high degree of scientific sophistication required to produce the kinds of specialty and pseudocommodity petrochemical-based products which are the strengths of the U.S. industry. 9/ In the meantime, though, the U.S. plastics and synthetic materials

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8/ Some industry experts expect that competitive pressures will force gas utilities to channel most of the still regulated "old" gas into the industrial market rather than into the residential or commercial markets. Most of the gas sold to the latter two markets is used for heating purposes and most residential/commercial heating plants do not allow for fuel switching. As a result, the demand for gas sold in these two markets is rather price inelastic. In contrast, the gas sold to the industrial sector is bought either in pure form, for use as a heart source, or in processed form, for use as a petrochemical feedstock. In each case, however, the U.S. industrial sector has an extensive capability to switch fuel with changes in the relative prices of gas, oil, and coal. Consequently, the industrial demand for gas is much more price elastic. With particular respect to SIC 282 industries, moreover, the price elasticity of demand for U.S produced natural gas liquids and natural gas-based petrochemical feedstocks will increase even more as new and cheaper supplies become available from Saudia Arabia, Mexico, and Indonesia etc.

9/ By 1986, however, Saudia Arabia will be producing low density polythylene, the largest volume plastics material, in a plant being constructed jointly with Exxon Corporation (see PART I: Section C).

industry could acheive major benefits, as the competition between the established and new-source petrochemical feedstock producers pushes down the price of the input which constitutes its major source of production costs.

These conclusions are consistent with a recent (1980) competitive assessment study from the Commerce Department's Office of Competitive Assessment (OCA). 10/ However, the OCA study was based on a set of eight petrochemical materials producing industries. Included in set of industries were three of the four industries which defined the present study (SIC's 2821, 2822, and 2824), with SIC 2823 being the the excluded industry. Moreover, the three included 282 industries represented approximately dnly 28 percent of the current dollar value of shipments by the eight OCA industries in 1981.

The OCA study divided the "total" petrochemical industry into the five state-of-process categories shown in the top row in Figure 61. The bottom row of Figure 61 shows the 23 industries (defined by 4-digit SIC codes) associated with each process stage. The OCA study dealt only with the eight industries engaged in the production of petrochemical materials -- primary petrochemicals, petrochemical intermediates, and petrochemical products. These industries are:

SIC	Title
2821 a/	Plastics Materials and Resins
2822 a/	Synthetic Rubber
2824 a/	Synthetic Organic Fibers
2843	Surface Active Agents
2865	Cyclic Intermediates, Dyes, and Organic Pigments
2869	Industrial Organic Chemicals
2873	Nitrogenous Fertilizers
2895	Carbon Black

a/ These three industries are also included in the present study.

The OCA study then further subdivides these eight industries into:

1. Commodity Petrochemical Products and Producers: high volume, low margin primary and intermediate petrochemicals which are undifferentiated and fungible, and sold primarily on the basis of price rather than quality. Examples include aromatics, olefins, cyclic aromatics, acyclic aliphatics, and fertilizers, etc. Industries producing these products include SIC's 2834, 2865, 2869, and 2873.

2. Pseudocommodity Petrochemicals Products and Producers: high volume products which are differentiated, designed to perform a physical or chemical function, and sold to performance standards. Examples include primarily thermo-plastic polymers such as low density polyethylene, high density polyethylene, polyvinyl chloride, polystrene, etc., plus carbon black). Industries producing these products include SIC's 2821 and 2895; in fact, the OCA study notes that 70% of SIC 2821 output consists of pseudocommodities.

10/ See citation in footnote 7.

3. Fine and Specialty Petrochemical and Petrochemical-Dependent Products and Producers:

3a. Fine Petrochemicals: Undifferentiated chemical compounds sold in small volumes, usually produced from purchased raw materials and frequently produced for one or more end uses to generally accepted specifications of chemical composition.

3b. Specialty Petrochemicals: Low volume, high margin, differentiated end products designed to solve specific customer needs, generally produced from purchased petrochemcical materials.

Examples of fine and specialty petrochemical products include engineering plastics -- acetals, ABS (acrylonitrile-butadiene-styrene), rigid vinyl, etc. -- used in building structures, boats, auto bodies, chemical plant equipment, appliance housings, and in exotic aerospace applicaitons -- adhesives, sealants, enzymes, dyestuffs, pesticides, and specialty elastomers and polymers of different kinds.

Importantly, the three 282 industries included in the OCA study are among the largest producers of these types of fine/specialty petrochemicals; SIC's 2865, 2869 and 2879 are also involved. OCA notes, for example, that the production of the U.S. synthetic rubber industry (SIC 2822) is concentrated in the production of specialty rubbers (e.g., specialty elastomers: high priced materials with unique properties, such as resistence to high temperatures or resistence to chemicals, which are finding increasings application in motor vehicles, aerospace, and high performance equipment) rather than in general purpose rubber production where most of the capacity of foreign countries is located.

The OCA study draws several conclusions which are particularly consistent with the conclusions reached in the present study for SIC 282 industries. These are:

1. Over the next 5-20 years the production of commodity petrochemicals in the geographic U.S. will become gradually less competitive, because of the dominant role that feedstocks and feedstock prices play in total production cost and the superior competitive position of new plants located in hydrocarbon-rich countries for the production of commodity petrochemicals utilizing indigenous natural gas feedstocks (OCA Summary Report: p.38).
2. Over time, the U.S. geographical-based chemical industry will restructure and move into growing markets for lower volume, high margin specialty chemicals and new performance-based pseudocommodity petrochemicals (OCA Summary Report: p.40).
3. The important focus for the future is the opportunities in downstream specialty chemicals and pseudocommodity petrochemicals (OCA Summary Report: p.55).
4. The U.S. industry has a number of advantages which will be important in sustaining its future international competitiveness including (OCA Summary Report: p.39).
    - highly developed technical base, including trained technical personnel and a tradition of emphasis on R&D and innovation;
    - an efficient, though now aging chemical infrastructure, supported by an

industrial infrastructure capable of supplying all materials/equipment needs, and an excellent transportation system;

- the diverse and non-monolithic nature of the industry itself, and the high level of competition domestically; and
- a stable political environment and free market orientation of the U.S. economy.

5. The decline in competitiveness of U.S. commodity petrochemicals is likely to be gradual, without precipitous crises that provoke calls for major federal action (OCA Summary Report: p.41).
6. The policy implications for the Federal Government associated with the decline in the international competitiveness of U.S commodity petrochemical do not appear to be that serious, particularly if this decline is offset by positive developments in the speciality and pseudocommodity chemical businesses (OCA Summary Report: p.41).

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